ON THE CONNEXION OF

GEOLOGY

WITH

TERRESTRIAL MAGNETISM:

SHOWING

THE GENERAL POLARITY OF MATTER, THE MERIDIONAL STRUCTURE OF THE CRYSTALLINE ROCKS,

THEIR TRANSITIONS, MOVEMENTS AND DISLOCATIONS,

INCLUDING THE

SEDIMENTARY ROCKS, THE LAWS REGULATING THE DISTRIBUTION OF METALLIFEROUS FORMATIONS,

AND OTHER TERRESTRIAL PHÆNOMENA.

BY

EVAN HOPKINS, C.E., F.G.S.

"Amid all the revolutions of the globe, the economy of Nature has been uniform, and her laws are the only things that have resisted the general movement. The rivers and the rocks, the seas and the continents, have been changed in all their parts; but the laws which direct those changes, and the rules to which they are subject, have remained invariably the same."—*Playfair.*

SECOND EDITION,
REVISED AND ENLARGED.

WITH THIRTY PLATES AND NUMEROUS WOODCUTS.

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PREFACE.

The First Edition of this Work was published about eight years ago, and has been for some time out of print, and in consequence of the numerous applications from practical men (engineers and miners) for a New Edition, and the gratifying manner in which the principles of the "Connexion of Geology with Terrestrial Magnetism" have been received and acknowledged by intelligent scientific men, and their important practical value to mining in all parts of the world, the Author has been induced to prepare this New Edition, with the hope of not only rendering these principles still more acceptable and useful to practical men, but also to show the necessity of revising what are called scientific doctrines, and bringing them within the bounds of actual demonstrations and practical utility.

The original object of this little Work was to point out the general order and uniformity of rocks, and the mode in which minerals are disseminated and concentrated therein; but it was found impossible to elucidate the laws of metalliferous deposits without giving a general outline of the

fundamental principles on which all the operations of terrestrial physics depend.

There is no branch in which there has been, and still is, so much capital expended without a general established principle to guide the public as mining—the opinion of an ordinary miner being often the only inducement to carry on a mine, and when two or three practical miners differ in their prospective opinions, there are no settled data founded by which the public can form a judgement who is right. Even the terms employed by some mining agents are so vague and ambiguous that many of the writers are incapable of explaining their real meaning, and consequently they are frequently improperly applied. Intelligent miners are always governed by indications with which they are familiar in their respective localities, which indications vary according to the general character of the local conditions; therefore if their experience happens to be limited to one district, they are liable to commit errors in judgement by taking the exceptions for the rules. These errors being committed so often, make the public look at mining as a lottery, and not as an ordinary enterprise, in which they can place dependence on the result. These unfavourable impressions lead others to think that the errors and the non-realization of mine-reports proceed from the want of scientific knowledge, and thus we find men of science, without practice, employed to give an opinion on the contents of mineral ground, who again bring forward untenable doctrines and improper data, from which to draw

their conclusions, being another extreme equally bad as the former.

With the view of removing some of these difficulties, and obtaining well-founded principles to guide us in our subterranean works, the Author, during several years' professional engagements in this pursuit, has occupied much of his time in the investigation of the subject, both in America and Europe; not merely as a consulting engineer, but likewise during the management of establishments, which have been under his entire charge for many years, and therefore his observations have been founded on real practice, and not from hasty surveys.

The principles here brought forward have not been assumed to account for certain phænomena in given regions, or borrowed from the conjectures of men of science; on the contrary, they have been established on *unequivocal and substantial facts,* and proved by many years' experience; so that their application will enable any *qualified* person to predict the general nature of the crystalline rocks, metalliferous aggregations, dislocations, and the character of the sedimentary deposits in all parts of the world with a degree of certainty hitherto unapproached by any science founded on the laws of physics.

Many of these principles will be still opposed by the professors of old doctrines and their theoretical students; however, this cannot interfere with the practical operations of the mining engineer; he may safely trust to the laws of terrestrial physics which have hitherto guided him in mechanical works, and leave results to prove who has the best

foundation. In conclusion, the Author hopes that his humble labours in the cause of industrial science, and the results of his practical experience in active operations during the greatest part of his life, combined with the local knowledge of intelligent practical men, will lead to a more satisfactory scientific training for mining than hitherto adopted, and ultimately render the mining branch of our national wealth more regular, certain and prosperous than heretofore.

Mining Record Office,
13 Austin Friars, London,
November 1, 1851.

*** The Author recommends those who study geology to get a well-selected and characteristic specimen of the principal rocks and minerals, so as to become familiar with their appearances and compounds. Mr. J. Tennant, mineralogist, of the Strand, has very good collections of such rocks, in cases of different sizes, suitable to geological and mineralogical students.

INTRODUCTION.

Although Geology has been brought, and now established as a distinct science, it must be admitted that the theories promulgated to account for the observed phænomena are in a most crude and unsettled state—frequently contrary to analogy, and not only unsupported by, but often in direct opposition to, the evidence afforded by the phænomena themselves. Indeed the valuable part of the science of Geology commonly taught, is the description of sedimentary beds, with their organic contents, combined with comparative anatomy, which division being somewhat more enchanting, has monopolized nearly the whole attention of geologists. When we refer to the common descriptions of the *primary* rocks and mineral veins, we find them so incorrect and so inapplicable to their general structure and conditions, and so mixed with hypothetical ideas, that those who have not the opportunity of studying Nature in her works, and who derive their knowledge from books, must imagine that the crystalline base is a confused igneous mass void of all order. Those however who have been taught in the field, and who are practically acquainted with the subject, have a very different opinion of their general character, and know well that the crystalline rocks possess an harmonious symmetrical structure and variable composition, governed by laws as beautiful as those observed in the forms of crystallization and in the vegetable kingdom.

There is scarcely a geological section furnished of the primary series by geological writers, in which the cleavage planes of the crystalline slates are not confounded with the planes of the sedimentary stratification; exhibiting veins with an overflow of melted matter, and also showing volcanic effects to explain phænomena with which they have no connexion. Every hornblendic vein is now called ancient lava; and igneous or volcanic rocks are terms commonly applied, not only to black rocks, but also to porphyritic masses, however moist they may be. We shall endeavour to show in the following pages, by innumerable and incontestable proofs, with *real sections*, that such a state of things does not exist; and also that there is no foundation whatever for assuming the existence of such an igneous element; and that the crystalline series with their enclosed mineral veins, are formed by polar forces according to geometrical laws, as uniform as any other physical phænomena of the material world.

In the study of the physical operations of Nature in search of truth, all preconceived ideas should be removed from the mind, and we should strictly trace the laws which govern the system, and reflect well on the evidence of phænomena and their legitimate connexions, whether they contradict or support the established doctrines. The science of Geology is of recent date, and is pre-eminently one of direct observation and very careful analysis, mechanically and chemically; requiring extensive examinations over large areas in many parts of the world to be justly comprehended. The want of this, and the tendency of the human mind to draw conclusions from an isolated phænomenon confined to a limited district, has been the cause of encouraging the hy-

potheses which are now prevalent, although totally incompatible to the observed physical operations. In entering into this subject, we must necessarily investigate the whole globe as we find it at present,—with its aërial, aqueous and semi-aqueous covering, permeated with the universal power of magnetism, and watch their combined operations throughout—the changes and sequence which actually belong to them, and follow their natural consequences.

Having once correctly ascertained the laws of causation regulating the changes and productions now taking place, we are more able to proceed from the known to the unknown by a legitimate process of induction. We must endeavour to keep ourselves strictly within the boundary of demonstration, taking nothing for granted; nor accept any assumptions; but confining our inquiries to existing laws, and the accumulated mass of unequivocal evidences lying before us, without adding to, or taking from them, their characteristic effects.

In perusing the following pages, it will be observed that the principles brought forward are not elucidated merely for the sake of showing the inconsistency of the igneous theory, nor to gratify idle curiosity in speculative questions, but to point out a general law in terrestrial physics, which is *simple* and *practically useful*, consistent with daily observations, and which has been successfully applied for several years in many parts of the world in mining and geological operations. Hence the views which the Author propounded many years ago still maintain their original ground, without any material alterations, notwithstanding his subsequent surveys in the Pacific, the Andes, and the Continent, and his daily experience in the profession in the principal mining districts.

The Author has been fully rewarded in the pleasure of developing new truths amongst the wilds of Nature, and rejoices in having had the opportunity of studying their connexion in that great school, even if he stood alone in admiring the harmony of these new principles in the works of the Creation. The reader will observe that the past was in accordance with the present—all subject to the changes produced by the great controlling power of terrestrial magnetism, thus impressing upon us the uniformity and unchangeable character of Nature's laws, and making us look up with solemn admiration to Nature's Author.

In leaving this interesting subject to the perusal of the attentive reader, the writer does it with a mind fully conscious of imperfections in the manipulations and other sources of error in matters of detail, yet he feels strong in the conviction of the *general* truths, inasmuch as they have been fully established, not alone from his own observations and practical applications, but also from those obtained from time immemorial, which have been so long neglected by the scientific world.

Although the various phænomena may be imperfectly described in consequence of the Work being but a mere outline, yet it is hoped that, by the aid of the accompanying illustrations, the main bearing of "*the Connexion of Geology and Magnetism*" will be comprehended, and found to rest on unquestionable data, without straining any fact, but simply following the legitimate consequences arising from cause and effect, obtained by direct examination and experiment, and capable of being understood by all who study nature.

OPINIONS OF THE PRESS.

"THE book contains very valuable information, somewhat closely connected with topics of great interest to this country . . . . . It is quite beyond my ability to give a fair analysis of this book; and I will conclude what I have to say by recommending those who are practically acquainted with the mineral condition of the country to peruse the chapter relating to the filling of veins. It seems to me to throw out lights which might or might not fall in with their local experience; but which would at all events afford matter for profitable inquiry and comparisons," &c.—*Sir Charles Lemon, Bart., M.P., President of the Royal Geological Society of Cornwall, in his Annual Address,* 1844.

"In this case, nature accomplishes on a large scale what experimentalists achieve with the galvanic battery; and if we admit the existence of subterranean currents, and that these exert a slow decomposing power, like that of the battery, we have sufficient power for our purpose . . . . . In this way may be explained the formation of veins that have long puzzled the geologist. This places geology and magnetism in quite a new light, disclosing a field of labour that promises a brilliant harvest to the persevering investigator," &c.—*Chambers' Journal.*

"Hitherto geological science has been designated as a vague and useless doctrine by many of our practical miners; and it is true that primary rocks, with their mineral veins, have been left by speculative geologists, as *terra incognita,* in complete obscurity; but we are happy to observe a change for the better; the science is beginning now to have a more useful and practical bearing, and men are getting more anxious to learn it; and it is to be hoped that with this combined influence and the diligent accumulations of new facts, such a degree of certainty will be obtained, as may enable them to predicate with some confidence, not only questions connected with mineral deposits, but likewise all phænomena which it comprehends. We have been led to make these observations on this interesting subject, in consequence of Mr. Hopkins's new system of Geology, which, owing to its practical applications to mining, and the satisfactory manner in which it accounts for all phænomena connected with terrestrial physics, is becoming an established system with practical men. The

interest has been considerably enhanced of late, owing to the recent discoveries made by the indefatigable Dr. Faraday, corroborating in a remarkable degree, Mr. Hopkins's general views, as explained in his work."—*Mining Journal.*

"The igneous theory—the doctrine of central fire—has for some time been slowly yielding to other views. All the phænomena attributed to fire may be produced (according to Mr. Hopkins's system) by electro-magnetic currents. It is difficult to imagine the existence of fires unsupplied with the oxygen of the atmosphere; . . . . Even the cause of the variation of the needle, mysterious as it has hitherto appeared to be, may be referred to the relative energies of the magnetic currents. The wasting away and degradation of the land, which have often been viewed with alarm, are now shown to be compensated for by a process tending to the renewal and perpetuation of the physical universe. We look forward to the labours of Professor Faraday as destined to throw further light on this interesting branch of science, in which he has already done so much. According to Sir John Herschel, we are to look to electro-dynamics for the *vera causa* of the Newtonian philosophy."—*Chambers' Journal, August* 1847.

"It is the best, and indeed the only principle hitherto propounded, which is capable of accounting for the various and complicated phænomena of geology, in a clear and satisfactory manner, in this, as well as in all other parts of the world, with which I am acquainted."—*Extract from a letter received from a geologist in Peru.*

"It is an acknowledged fact by all miners that the geology commonly taught is of no avail to them, and even the character of the primary rocks and the mineral veins is so imperfectly described, as to mislead those who study them from the ordinary books and lectures on geology. It is admitted also, that the only practical system of geology applied to mining, and now used by mining engineers, is 'Hopkins's Geology and Magnetism.'"—*Mining Gazette.*

CONTENTS.

ON THE CONNEXION OF GEOLOGY WITH TERRESTRIAL MAGNETISM.

CHAPTER I.

ON THE POLARITY OF MATTER UNDER THE INFLUENCE OF THE EARTH'S MAGNETISM.

UNTIL very lately the term Magnetism was considered as applying solely to magnetic needles, bars, horse-shoe magnets, and various steel toys, which have been looked on by the world as possessing some singular inherent active principle, and not that their movements depended on the effect of an universal external power, to whose influence they had been made sensitive.

It is proved by numerous experiments that we are always enveloped in this great polar force: the most impermeable envelopic substance we can employ, and the most perfect air-pump to exhaust, cannot extract nor weaken its powers. Its directive polar force, attractive power, and effect on matter to crystallize, are equally strong under an exhausting receiver; be that in the air above, in the rocks below, or in the depths of the ocean.

This subtile power permeates all matter, causing a never-ending process of activity, both chemical and mechanical, beneath the scene of life; giving form and internal structure to the crystalline film on which we have an existence, and is the most important agent in the general œconomy of nature.

This great prime mover is always present; has been, and still is, our unerring guide across the ocean, amidst cloudy skies, or in the darkest nights on every spot of the globe; and is also the

faithful guide of the miner in his subterranean explorations, and the most rapid agent of intercourse between distant towns. It is silently working within and without, perpetually forming, moving and modifying our terrestrial habitation, and rendering it suitable to our wants during all ages of transformation, and constantly providing stores of mineral wealth for successive generations.

It has been long known that if a magnetic bar be supported in such a manner as to have entire freedom of motion in a horizontal plane, it will, after a few oscillations, finally settle in a position directed more or less north and south. If disturbed from this situation, and placed in any other direction, it will, as soon as it is again at liberty to move, resume its former position. The two ends are called its Poles; the one which turns to the north being distinguished as the *north*, and the other as the *south* pole. The tendency of the magnet to assume the above described position is called its polarity; on this property is founded the mariner's compass. When we reflect on the great benefit mankind has derived from the polarity alone of magnetism, and which has so much contributed to the exploration of distant regions and to the advancement of the civilization of the human race, it must necessarily create a desire to learn something more of its general character.

It was considered for a long time that the only substance susceptible of polarity was iron and its compounds, but subsequent discoveries have proved that there is no substance but which, under suitable circumstances, is capable of exhibiting unequivocal signs of the magnetic influence, *i. e.* radial attraction, and the usual polar phænomena; and this not only in solid matter, but also in oxygen and carbonic acid gases.

In order to prove that the polarity of matter is merely the effect of the earth's magnetism, let an ordinary steel bar be buried in the ground in a north and south direction for a few months, it will be found that the bar if taken up and thrown into a trough of mercury will gradually place itself, if left undisturbed, in the exact position end for end as it previously occupied. If the same bar be placed again in the earth for a given period in a reversed direction, it would, when replaced on the mercury or delicately suspended, maintain this reversed po-

sition, showing most distinctly that its polarity depended on the direction in which it was rendered sensible to its influence when in the ground.

This effect is not confined to steel bars; any rock of the primary series, but more especially the ferruginous, if cut from the parent rock *in situ*, and suspended or floated, would take the exact position it occupied in nature; be the piece of rock an inch, a foot, a yard or a mile, the effect would be the same. Consequently, if an island, or even a continent, could be placed raft-like to float on the ocean, it would take a direction corresponding to the one it originally occupied, as the polar influence on the rocks is the same, individually and collectively.

The crystalline rocks constituting the solid surface of the globe are all more or less magnetic. The mountain of Regelberg in Germany, which consists of serpentine, is highly magnetic; its south side attracts the north pole, and its north side the south pole of a magnet.

Indeed it is well known, although not always duly considered, that the magnets were originally cut and made out of a rock called a *loadstone*. The polarity of masses of rocks have been observed in every part of the world—in the straits of Magellan, along the whole range of the Andes, in the isthmus of Panama, Mexico, the Rocky Mountains in North America, the Arctic regions, Scotland, and in various parts of the continents of Europe and Asia.

Plates IV. and V. show the average direction of the position of the magnetic needles in different parts of the globe. On reference to the Plates, it will be observed, that notwithstanding the numerous external disturbing causes such delicate needles must be subject to, they nevertheless preserve a remarkable degree of uniformity from pole to pole. The western deflection appears to predominate, the apparent cause of which will be discussed in another chapter.

These lines, which are commonly called magnetic meridians, are perpetually varying; not only from general causes, but from local effects and configurations of the dry lands; and are differing in the angle of variation even in the same meridian, being easterly in one place and westerly in another.

The name *magnetic meridians* has been applied to those lines

formed by the position of the magnetic needles as described in the Plates. A line drawn at a right angle to them near the equator is called the magnetic equator, and to such a line a much greater importance has been attached than it deserves. In fact it is difficult to conceive what a line drawn across an undulating linear current can have to do with the question.

Surveys made solely by compass and without the usual checks for corrections for magnetic variations, cannot fail to produce great confusion in the boundary lines between different properties, or in carrying on new works in old mines from lines laid down in old maps.

I remember a case in point abroad where the variations had increased about 2° since the old survey and map had been made, and where certain new communications were required, which, had they been made by the compass and the old mapping, would have led to a very expensive error. This was prevented by my taking timely observations. Numerous properties as well as mines would be brought into endless litigation by the continual variation in the direction of the magnetic needle if places were constantly laid down and measured from the local meridian of the needle instead of the true.

The direction of the magnetic needle in England about 250 years ago was 11° east of north, it is now about 24° west of north; it is constantly undergoing a slow oscillation.

The following Table shows the change which has taken place in London from the years 1576 to 1850:—

Years.	Variations.	Years.	Variations.
1576	11° 15′ 0″ Easterly.	1774	22° 20′ 0″ Westerly.
1580	11 17 0 ,,	1778	22 11 0 ,,
1622	6 12 0 ,,	1790	23 39 0 ,,
1634	4 5 0 ,,	1800	24 36 0 ,,
1657 } 1662 }	No Variation.	1806	24 8 0 ,,
		1813	24 20 17 ,,
1666	0 34 0 Westerly.	1815	27 27 18 ,,
1670	2 6 0 ,,	1816	24 17 9 ,,
1672	2 30 0 ,,	1820	24 11 7 ,,
1700	9 40 0 ,,	1823	24 9 40 ,,
1720	13 0 0 ,,	1831	24 0 0 ,,
1740	16 10 0 ,,	1840	24 0 0 ,,
1760	19 30 0 ,,	1850	24 0 0 ,,

Besides the progressive changes in the direction of the needles, there are annual or periodical movements and daily oscillations constantly taking place in all parts where magnetic observations have been made. The dip of the needle, like the horizontal variation, has different values in different parts of the globe; on an average being horizontal near the equator, and perpendicular to the horizon at the poles. Hence, if a magnetic needle were to be balanced at the equator, it would be found to decline from its horizon as we proceed from thence towards the poles: its average position forms a curve, called the 'Magnetic Curve,' from pole to pole, as shown in Plate IV.

On looking at the general direction of the magnetic curves and the magnetic meridians, we observe that they tend to converge at the poles, notwithstanding their deflections and undulations from various local disturbances. Numerous fruitless investigations have been made with the view of ascertaining the position of the magnetic poles, as if these were *mathematical points*.

Any person who has had experience with the action of fluids, whether water, air or electric, converging towards or diverging from a central passage, must know that they cannot be forced into a *mathematical point*; there must be a limit to their compression or density; nor can it be expected that every individual current should retain its exact radial course towards the focus, and much less when diverging from it. Hence from analogy and observations, the narrowest limits that we can assign to the polar axis to which the magnetic currents converge and diverge are, perhaps, the areas bounded by the arctic and antarctic circles.

By taking these extensive spaces for the magnetic poles, we shall be relieved from entering into the useless and endless inquiries respecting late discoveries, and formulas which have been established or founded on them. The question is rendered simple, not requiring formulæ which profess great accuracy in points where the data of observation must be very uncertain.

Numerous observations have been made in the equatorial regions, indicating both east and west variations in the *same meridian* of only a few leagues in extent, proving that the direction of the needle does not necessarily point towards the centre of convergence of the currents, but in the direction of the local

deflection. The position of the needles may be compared to what they are when suspended over a long undulating telegraph wire. They do not point in the direction of the main current, but are all deflected proportionally to the intensity of the electricity passing through the wire and the angle of the bends. The local disturbing force being a variable quantity subject to perpetual fluctuations, it follows as a consequence, that the variations of the direction must be uncertain, and therefore not within the power of any formulæ to know their periodical amount.

In the above our observations have been principally confined to the direction of the needles; but as it is proved that the needles only indicate the presence of an universal power, and since we cannot withhold our conviction, after tracing the curves which the needles form within, on, and above the earth, that the globe is a magnet, *i.e.* that its axis is magnetic, and according to the law of magnetism, founded by direct experiment, the *north* end is the attractive and the *south* end is the repulsive, or in plainer language, that the magnetic currents move towards the north, then absorbed by the axis, issue out again from the south pole and encircle the globe to complete their circuit (as indicated by the direction of the needles, and illustrated by the arrows in the following sketch).

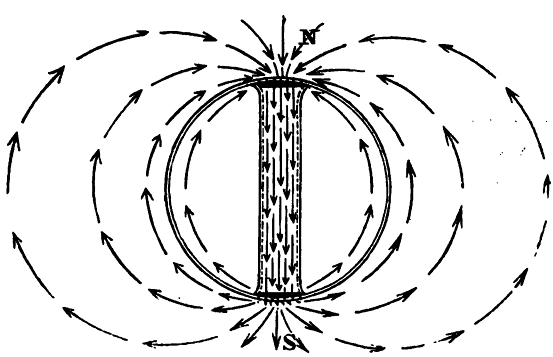


Fig. 1.

If the earth then be a magnet, its magnetism must produce the effects observed; if it be not a magnet, it possesses at all

events a property identical in its results to one; therefore all we require in our investigations is the knowledge of the law of these actions, as the mere *name* of the primary cause of this spherical principle of activity cannot have a material influence with our researches. If we call it *gravitation*, we must add to it a property which was not applied to it before, viz. polarity,—call it *magnetism*, and the term embraces all we require in the various physical operations incessantly going on within, and on the surface of our terraqueous globe*.

Let us suppose a bar, having been made magnetic, to be placed in the axis of an artificial globe; if iron filings be strewed carefully over it, the filings would become magnetic, and arrange themselves in curves like the magnetic needles on our globe, as shown in Plate I.

The small magnetic ingredients do not converge to one mathematical point at each end of the bar, but to a space equal to the transverse section of the axis; and if this effect is produced by a current of subtile fluid, which may be conceived to emanate from one pole and to enter in at the other, permeating the bar, and again issuing from its former outlet, as exhibited by the arrows in the above diagram, it is reasonable to suppose that the fluid will not be compressed more than the transverse size of the bar will require. Taking this simple principle of action as a guide, with its various consequences under different circumstances, we shall perceive that we not only account for the various phænomena of geology, but, in a word, *all* phænomena connected with terrestrial physics; and that we are enabled also to reason from the known to the unknown, and actually to predict facts before trial, not merely to satisfy curiosity, but questions of practical utility. Indeed, theories are not worthy of attention unless they can be fairly demonstrated, and rendered practically useful, and elucidated in simple and clear language.

To proceed with our subject, let us place the above bar on a centre, or to float on water, we shall find it will take a meridional

* It has been supposed by many that the terms positive and negative, and attraction and repulsion, represent two distinct qualities or principles of action. To avoid such erroneous notions influencing the mind of the reader in the perusal of these pages, or at all events to prevent misconceptions in our present inquiry, it must be distinctly understood that the opposite poles are only considered as the *absorbing* and *evolving* points of activity through which the circulating power permeates, and not distinct qualities.

position; it is therefore manifest, that by some internal action the iron bar is rendered susceptible of allowing the polar stream to pass through it *only in one direction*, viz. *from the south to the north end of the bar.* If we cut the bar into several pieces, what would be the result, supposing that by so doing we do not injure its magnetic susceptibility? Might we not reasonably expect the same phænomena in the separate parts as when entire, viz. that the polar action would still preserve its definite direction through the separate pieces as when entire? Such is the fact; every portion of the fractured magnet is a magnet perfect in itself, *i. e.* each has a north and a south end corresponding to their united position. Similar effects ensue from the subdivision of one of these fragments into any number, however great; and if reunited, by placing them together again in the same position, the result would be the same; that such would be the case is very evident, as the separation of the magnetic bar, provided it be effected without injuring its magnetic properties, only diminishes the length of the pores, not changing or altering the natural direction imparted to it originally.

This reasoning will show that two similar poles must repel one another, and that two dissimilar poles attract each other, owing to the tendency of the circulating currents to obtain a free passage, each being deflected according to the quantities of their æthereal volumes of activity and respective amounts of resistance. The intensity of the action must be as the density; and if we assume that the whole of the circulating currents round the magnet, within a certain limit, are converged into the polar focus, their intensity must increase towards that point inversely as the square of the distance; like any other fluid, air, water, or steam, which may converge to, or diverge from, a central passage. Consequently we can determine the resultants of the forces which may act upon a magnetic needle when its centre is situated in different directions relatively to the axis of another magnet; and what will be its movements, and what its final position of equilibrium. This is an amusing and very instructive mode of experimenting, and may be elegantly explained on a table, with a series of pocket compasses and bar magnets.

In placing needles round an artificial globe, we find them arranging themselves in the exact order as seen on the terrestrial

globe, both as to dip and direction; but as there is nothing to disturb them in the former, their positions in the curves of convergence are uniform, and equal to the transverse area of the magnetic axis at both ends.

We find in measuring the force along the magnetic curves, that it varies inversely as the distance: allowing for the influence of the earth's magnetism, and tracing the effects in a horizontal plane, we obtain the following law, viz. *that the force varies inversely as the square of the distance from the surface of the ball in the equatorial plane, and also in the meridian from the poles towards the equator*; being the necessary consequence of the expansion and compression of the magnetic power: this is precisely the law of what is called gravitation. The meridional variation towards the poles of the earth has been hitherto ascribed to the effect of a centrifugal force produced by the earth's rotation, and is also considered as the cause of the earth being an oblate spheroid. A globe constituted under similar conditions as our earth is, with its enveloping fluids placed under the influence of centripetal and centrifugal forces, according to the well-known laws of physics, could not produce the observed figure, much less the variation of attraction towards the poles. Such effects as those ascribed to rotation are not known at the equator. As the surrounding atmosphere rolls with it, the surface cannot be exposed to rotatory effects. Its magnetism alone, without rotation, must necessarily compress the poles, and also cause the inverse law of intensity in the enveloping fluids.

In order to show further that there is no necessity for a rotatory or centrifugal force to cause or at least to preserve an oblate spheroid in a similar body, let us take the moon as an example. She is an oblate spheroid, yet she does not rotate, *i. e. on an axis situated within her body,* because she always presents the same face towards the earth. Magnetism alone forms a spheroid by the variable intensity of the currents, and this effect is observed from the dew drop to the magnitude of the celestial globe. Methods have been devised for measuring the attractive force of the whole globe, compared to that of some of its parts; according to which it has been inferred that the density and specific gravity of the globe is nearly five times as great as that of water. Calculations of this kind are liable to

error, inasmuch as the attraction of a *hollow* shell is equal to a *solid* one.

If this be the primary agent by which all the substances of our globe are governed, we ought to be able to trace its effects according to the above principles of action, viz. circulating from south to north over the surface of our earth, with a force varying inversely as the square of the distance from the respective centres. Commencing with the *atmosphere*,—We see the luminous appearances connected with the poles of our earth, called aurora borealis and australis, corresponding to the curves of convergence towards the poles, as shown in the following sketch.

When these luminous phænomena display unusual brightness and activity, the magnetic needle is found very fluctuating, both in dip and direction, the mercury in the barometer being often subject to similar action. This coincidence of the movements indicates that they are produced by the same cause, viz. the disturbance of the equilibrium of the tension of the enveloping magnetic power.

The horary variations of the barometer within the tropics present two maxima and two minima—the former at 11 A.M. and about the same time at night, and the latter, 5 P.M., and a corresponding period in the morning, as will be observed in perusing the following tables *.

* I am indebted to Mr. Albert Dumaresq, my assistant, for his indefatigable assistance in registering these observations day and night, during a portion of my last researches in Equatorial America.

BAROMETRICAL OBSERVATIONS.

Santa Marta.

Latitude 11° 14′ N. Long. 74° 14′. 13 ft. above the level of the sea.

1844.	Barometer.					Remarks.
	Hour.	Height in inch.	Temp. Mer.	Temp. Air.	☽'s Age.	
			°	°		
May 10.	12 a.m.	29·938	86·50	85·50	☾	Dry and windy*.
	3 p.m.	29·920	84·50	84·0	...	Showery.
	9 p.m.	29·960	82·50	82·50	...	Cloudy.
	6 a.m.	29·918	81·50	81·50	...	Cloudy.
	9 a.m.	30·280	82·00	82·50	...	Cloudy and showery.
11.	12 a.m.	29·980	83·00	82·00	...	Showery.
	3 p.m.	29·932	81·00	81·00	...	Thunder and { temp. of rain 80°.
	6 p.m.	29·932	81·50	81·20	...	heavy rain { temp. of air 82°.
	9 p.m.	29·966	81·00	81·00	...	Very wet.
	6 a.m.	29·980	81·00	80·50	...	Cloudy.
	9 a.m.	29·980	81·00	81·00	...	Heavy rain.
12.	12 a.m.	29·958	82·20	82·00	...	Cloudy.
	3 p.m.	29·908	82·00	81·50	...	Cloudy and showery.
	6 p.m.	29·900	80·50	80·50	...	Showery.
	9 p.m.	29·940	81·50	81·50		
	12 p.m.	29·924	81·00	81·00		
13.	3 a.m.	29·900	81·00	80·50		
	6 a.m.	29·944	81·00	81·00	...	Fine clear day. [when high tide.
	9 a.m.	29·970	82·00	82·00	...	High water; tide about 18 inches
	12 a.m.	29·942	84·00	83·50	...	Dry and windy.
	3 p.m.	29·888	82·00	81·50	...	Heavy showers and thunder.
	6 p.m.	29·996	81·50	81·50	...	Thundering.
	9 p.m.	29·944	81·00	81·50	...	Heavy rains, thunder, windy.
14.	6 a.m.	29·910	81·00	81·00	...	Cloudy.
	9 a.m.	29·994	81·00	81·00	...	Clearing up a little.
	12 a.m.	29·988	83·00	83·00	...	Dry.
	3 p.m.	29·870	82·50	82·20	...	Cloudy, but dry.
	6 p.m.	29·870	82·20	82·20	...	Windy.
15.	3 a.m.	29·924	81·00	81·50	...	Cloudy.
	6 a.m.	30·000	81·00	81·00	...	Dark clouds, thunder and lightning.
	12 a.m.	30·036	79·50	79·50	...	Heavy showers and thunder.
	3 p.m.	29·950	78·50	78·50	...	Showery and dark clouds.

* Temperature of the Carribean Sea:—

	°
Surface	83
240 fathoms deep	48
386 ,, ,,	43
450 ,, ,,	42
500 ,, ,,	41

Table (continued).

1844.	Barometer. Hour.	Height in inch.	Temp. Mer.	Temp. Air.	☽'s Age.	Remarks.
			°	°		
May 15.	6 p.m.	29·974	78·00	78·00	...	Dark cloudy evening.
	9 p.m.	30·012	78·00	78·50	...	Very wet.
16.	6 a.m.	30·000	78·50	78·50	...	Fine morning, but cloudy.
	9 a.m.	30·042	79·00	79·00	...	Fine morning, but cloudy.
	12 a.m.	29·986	81·50	81·75	...	Dry and hot.
	3 p.m.	29·934	82·00	82·00	...	Dry and hot.
	6 p.m.	29·930	83·00	82·00	...	Clear sky*.
17.	3 a.m.	29·944	80·50	80·50	●	
	6 a.m.	29·970	80·20	80·50	...	Fine morning.
	9 a.m.	30·000	81·75	81·75	...	Fine morning.
	3 p.m.	29·936	85·20	85·00	...	Clear sky.
Santa Ana. Latitude 5° 10′ N. Long. 75° 0′ W. 3000 ft. above the level of the sea.						
Sept. 2.	3 p.m.	27·600	77·00	77·00		
3.	9 a.m.	27·150	75·50	75·50		
4.	5 p.m.	27·380	77·00	77·50	☾	
5.	8 a.m.	27·162	74·50	74·50		
	3 p.m.	27·260	79·00	79·00		
	9 p.m.	27·124	76·50	76·50	...	Cloudy.
6.	12 a.m.	27·132	74·00	74·00	...	Wet morning.
	·6 p.m.	27·180				[after 11, noon.
	10 p.m.	27·150	....	74·50	...	Stationary about 11, and sinking
21.	10 a.m.	27·234	72·50	72·50	...	Very foggy; damp.
	11¼ a.m.	27·154	72·00	71·50	...	Very foggy; damp; very windy.
	12 a.m.	27·130	72·50	72·50	...	Clearing up; very windy.
	1½ p.m.	27·114	74·75	74·00	...	Clearing up; very windy.
	3½ p.m.	27·440	74·00	74·00		
	9½ p.m.	27·138	73·00	73·00	...	Cloudy and calm.
	12 p.m.	27·146	73·00	73·00	...	Cloudy and calm.
22.	8½ a.m.	27·146	72·00	72·00		
	2 p.m.	27·540	75·00	75·00	...	Cloudy and mild.
	3 p.m.	27·500	....	....	...	Shock of an earthquake.
	11 p.m.	27·130	74·50	73·00		
23.	9 a.m.	27·170	71·00	72·00	...	Cloudy and rainy.

	°	′
* Declination north at 6 ..	19	17
Latitude	11	14
	8	3
Azimuth from mag. meridian	283	35
270°+8° 3′=	278	03
Mag. var. E.	5	32

TABLE (continued).

1844.	Barometer.					Remarks.
	Hour.	Height in inch.	Temp. Mer.	Temp. Air.	☽'s Age.	
			°	°		
Sept. 23.	2 p.m.	27·116				
	9 p.m.	27·154	73·50	74·00		
24.	3½ p.m.	27·180	75·50	75·50	...	Cloudy and damp.
25.	7 a.m.	27·146	73·00	73·50	...	Cloudy and damp.
	9½ a.m.	27·218	73·00	73·00	...	Cloudy.
	2 p.m.	27·110	75·00	75·50	...	Cloudy.
	3 p.m.	27·680	75·50	76·00	...	Clearing.
	7 p.m.	27·110	74·50	74·50	...	Cloudy.
	10 p.m.	27·170	73·50	74·00	○	Thunder and wind.
26.	7½ a.m.	27·170	76·00	76·00	...	Fine morning.
	12 a.m.	27·168	75·50	75·50	...	Fine, but rather cloudy.
28.	9½ a.m.	27·220	72·50	72·50	...	Foggy and rainy.
	1½ p.m.	27·144	74·50	74·50	...	Cloudy.
	4 p.m.	27·840	75·00	75·00	...	Cloudy.
	10 p.m.	27·176	74·00	74·50	...	Showery.
29.	8½ a.m.	27·250	74·00	72·50	...	Thick, wet and foggy.
	2 p.m.	27·134	73·00	73·00	...	Clearing up.
	9½ p.m.	27·196	72·50	72·50	...	Cloudy.
30.	7 a.m.	27·214	72·50	72·50	...	Mild morning.
	9½ a.m.	27·250	72·00	73·00	...	Cloudy.
	1 p.m.	27·188	74·00	74·00		
	3½ p.m.	27·134	75·00	75·00	..	A little cloudy.
	4 p.m.	27·124	75·00	75·50	...	A little cloudy.
	5 p.m.	27·124	75·00	74·50	...	Clear sky.
	7½ p.m.	27·124	74·00	73·50	...	Clear sky.
	9½ p.m.	27·184	74·00	73·50	...	Clear night.
	10½ p.m.	27·184	73·50	73·50	...	Cloudy.
	11½ p.m.	27·184	74·00	74·00		
Oct. 1.	6½ a.m.	27·180	73·00	72·50	...	Fine morning.
	1½ p.m.	27·170	75·00	75·50	...	Light clouds.
	5 p.m.	27·920	75·50	75·00	...	Light clouds.
	6 p.m.	27·920	75·00	75·00	...	Light clouds.
	8 p.m.	27·138	74·50	74·50	...	Light clouds.
	10½ p.m.	27·174	74·50	74·50	...	Light clouds.
	12 p.m.	27·176	74·00	74·00	...	Light clouds.
2.	7 a.m.	27·176	72·00	72·50	...	Wet morning.
	10 a.m.	27·200	72·00	72·00	...	Low clouds. [ning.
	8 p.m.	27·120	74·00	74·00	...	Stormy night; thunder and light-
	12 p.m.	27·150	73·00	73·00		
3.	11½ p.m.	27·180	74·00	74·00		
4.	5 p.m.	27·260	74·00	74·00	☾	
5.	9 a.m.	27·234	73·00	73·00	...	Heavy rain.
6.	8 a.m.	27·268	71·50	71·00	...	Heavy rain.
8.	7½ a.m.	27·258	71·00	71·00	...	Light rain.
11.	11 p.m.	......	...	...	...	Shock of an earthquake.
12.	7½ a.m.	27·210	72·00	71·¼	...	Low clouds.

Marmato.

Latitude 5° 24′ N. Long. 75° 50′ W. 4258 ft. above the level of the sea.

1845.	Barometer. Hour.	Height in inch.	Temp. Mer.	Temp. Air.	☽'s Age.	Remarks.
			°	°		
Feb. 3.	12 a.m.	25·628	72½	72¾	26	Dry and windy.
	7½ p.m.	25·600	74	74¼	...	Fine night.
4.	7 a.m.	25·656	70	70	27	Fine morning. [night.
5.	8 a.m.	25·700	69½	69	28	Cloudy damp morning and wet
	10½ p.m.	25·688	71	70	...	Damp night and clear sky.
6.	7½ a.m.	25·688	67	67	●	Foggy morning.
	11 p.m.	25·600	71	70½	...	Fine starlight night.
7.	7½ a.m.	25·656	68	68	...	Dry and windy. [this evening.
	6½ p.m.	25·636	73	73¾	...	Fine, but cloudy; a slight shower
	9 p.m.	25·700	73	72½	...	Cloudy.
8.	7½ a.m.	25·714	69	69½	...	Wet morning.
	5½ p.m.	25·600	73½	73	...	Fine, but cloudy evening.
	11½ p.m.	25·650	70½	70	...	Fine starlight night.
9.	8½ a.m.	25·684	67	67½	...	Fine morning.
	12 a.m.	25·658	72½	72½	...	Fine day, windy.
	2½ p.m.	25·600	73	72½	...	Fine day, windy.
	9½ p.m.	25·670	72	71½	...	Starlight night.
10.	7½ a.m.	25·686	68	68	...	Fine morning.
	12 a.m.	25·660	71½	71½	...	Fine morning.
	10½ p.m.	25·684	72	71	...	Fine starlight night.
11.	12 a.m.	25·660	70	70½	...	Fine day.
	4½ p.m.	25·620	72½	72½	...	Cloudy evening. [clouds.
	11 p.m.	25·716	71½	71	...	Starlight night, but with some
	11¾ p.m.	25·730	71	70½	...	Heavy shower, with sharp claps of thunder and lightning.
12.	7 a.m.	25·730	69	68½	...	Damp and foggy.
	2 p.m.	25·684	72	71½	...	Light showers.
	10 p.m.	25·734	69	69	...	Starlight night.
13.	7½ a.m.	25·770	66	66	...	Fine, but low clouds.
	12 p.m.	25·740	70	70	☽	Fine day, light clouds.
April 9.	6 a.m.	25·586	73½	73½	...	Fine sunny morning.
	10 a.m.	25·712	74	74	...	Fine, but little cloudy.
	12½ a.m.	25·660	74½	74½	...	Fine, but little cloudy.
	2½ p.m.	25·636	74½	74½	3	Low clouds, thundering at a distance, and slight rain. [rain.
	10½ p.m.	25·716	73½	73½	...	Stormy, thunder, lightning, and
10.	7½ a.m.	25·720	71	71	...	Fine morning.
	10 a.m.	25·716	71½	71½		
	12 a.m.	25·650	73	73	4	Hot, but cloudy. [bourhood.
	4 p.m.	25·608	74	74	...	Showery, thundering in the neigh-
	7 p.m.	25·620	72½	72½	...	Cloudy.
	10 p.m.	25·680	72	72	...	Cloudy, lightning southward.

The regularity of this rise and fall of the mercury within the tropics below the elevation of 3000 feet above the level of the sea, is seldom disturbed by the change of weather; and we may, with a good barometer, such as I had, infer the hour of the day from the height of the column of mercury.

We observe the same regularity in the variations of the magnetic needle. From 8 A.M. the needle is gradually deflected until 2 P.M., at which period, during the strongest heat of the sun, the needle occupies the maximum westerly variation, and returns to the eastern angle of the arc in the coolest part of the day. This variation is like the oscillations of the mercury, viz. greater near the polar regions than at the equator.

The recent brilliant discoveries of Professor Faraday have established the intimate relations between the electric tension of the atmosphere and the electro-magnetic condition of the earth; and that this influence is as much apparent in the gases oxygen and nitrogen, as in their combination with other substances.

The aurora is the effect of polar activity, excited to the production of a luminous phænomenon; an activity which often manifests itself from pole to pole in meridional bands of white clouds*. The evolution of polar lights may be the indication of the restoration of the equilibrium in the distribution of the aërial electro-magnetic force.

On the days when the southern aurora takes place, the same phænomenon is observed in the north, and therefore simultaneously produced like the lights produced by an artificial magnet.

If this permeating power emanates from the south pole and proceeds to the north, thence returning into the axis to complete its circuit of activity, we should expect a difference of appearances in the south aurora as compared with the north: the former rises from an aqueous element, whilst the latter descends from the aërial towards the polar axis. We find the southern aurora, generally speaking, presenting the appearance of long columns of clear white light, shooting up from the horizon to the sky; the figure being in every respect similar to the northern lights, with

* This phænomenon I have frequently witnessed in the Atlantic and Pacific oceans.

the exception of their being of a whitish colour. The northern lights assume more fiery tints of purple hue.

The saturated hydrogenous character of the aërial polar force coming from the south pole, will account for the observed peculiarity of the southern hemisphere in its temperature, moisture, rains, the growth of gigantic vegetation, &c., as compared with the northern hemisphere.

Hence the great ocean of air which envelopes the planet we inhabit, to which we are every instant beholden for supplying us with the elements of vitality, is permeated and bound into a sphere by this magnetic power. Whatever substances may be decomposed and converted into gases and rise to the atmosphere, are again returned into the earth. Nothing can escape or be destroyed: they are made to combine and continue active agents in the business of the world, and main support of vegetable and animal life, and are still susceptible of running again and again the same round as circumstances of terrestrial operations may determine.

CHAPTER II.

THE IDENTITY OF THE PRINCIPLE OF MAGNETIC AND GALVANIC FORCES.

Although the sciences of magnetism, galvanism and electricity have been effectually blended, and proved by various experiments to be the effects of one primary cause, the direction of the magnetic currents compared with galvanism is considered different, *i.e.* that the magnetic currents move at right angles to those of galvanism. This idea has arisen from the effects of the *spiral* course in which the external current that envelopes the connecting wire of a battery moves towards the negative plate. For instance, if the connecting wire of a battery, or the wire of an electric telegraph, be placed in the meridian, having its negative plate attached to the north end and the positive plate to the south, the external current enveloping the wire will move northward towards the negative plate in a spiral form. On the

upper side of the wire it moves towards the north-west, and on the under side towards the north-east; on the western side it moves downwards, and on the eastern side upwards. This spiral nature of the current produces motion in a circular direction round the wire, which is exhibited in various electro-magnetic machines. The direction of the external current is thrown into a spiral course, proportionably to the intensity of the force and resisting power of the internal streams. Supposing the intensity of the current causes the needle when held above the wire to deviatc thirty degrees to the west, in placing it underneath the wire it will deviate thirty degrees to the east; taking the mean of the two, we find that the direction corresponds to that of the wire.

It is a singular fact, that the creeping or entwining plant, if in the neighbourhood of a trunk of a tree, will approach and grow round it in one definite and constant spiral direction; yet both possess the same directive principle of ascending force, as shown in the following diagram*, fig, 1.

Fig. 1.

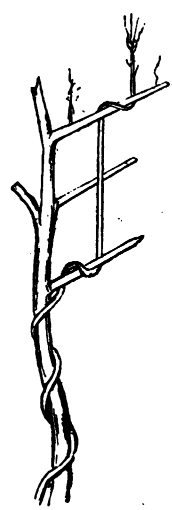


Fig. 2.

The magnetic needle in the presence of the galvanic wire exhibits the same spiral phænomenon, as illustrated by fig. 2.

* This interesting subject, connected with the physiology of vegetation, will be entered into in another chapter.

All known forces, emanating from a certain point and exerted upon another point, act in the direction of the line joining these two points. Such is the effect of a stream of water on a substance exposed to its action, and on a vane by the wind, which always points in the direction of the current. The same law applies to electric and magnetic actions, in all the cases that belong exclusively to the one or to the other, and are only deflected by their mutual resistances.

When two conducting wires, bent into helices, act upon one another, which they do in a manner that imitates exactly the mutual effect of two magnets, it is called electrical, and is exerted in the lines of direction that join the acting points. The same is the case with two magnets. When the latter is exposed to the influence of the former, it causes the spiral current above alluded to. All fluids, when forced through tubes by a great force, have a tendency to move in a spiral direction, as commonly observed in a funnel, water falling through pipes, or a stream of air forced through a tube. However, if we take the mean of the direction of the spiral, we find that it corresponds to the direction of the wire; therefore we may consider that the magnetic needle, enveloped as it is in the great terrestrial magnetic fluid, is only slightly deflected westward from the direction of the subterranean stream, but yet indicates the direction of the external currents.

In the battery we find that the currents of hydrogen move from the zinc to the silver plate, along or through the connecting wire. We find by experiments that the south pole of a magnet has a greater affinity for oxygen than the north pole. The difference in the oxidation of the south pole, compared with the north, is easily proved by various simple methods. All that is required is to place the ends of a magnet in water, and allow it to remain undisturbed for several days, and the fact is soon proved. A very powerful horse-shoe magnet will decompose water, and the oxidation will be observed to go on at the south pole, and the evolution of the hydrogen at the north pole *: hence it is manifest that the currents move from the south pole to the north pole

* These poles are named according to their position, and contrary to the great terrestrial poles, inasmuch as the north pole of the magnet is the evolving, whilst that of the earth is the absorbing pole.

of the needle: the magnet possesses the property of *filtering*, as it were, *the oxygen from the polar stream.*

Ritter asserted that a needle, composed of silver and zinc, had arranged itself in the magnetic meridian, *i.e.* the zinc towards the south and the silver towards the north, and was slightly attracted and repelled by the poles of the magnet: to effect this the air must be very moist. Generally speaking, such needles can only act when immersed in liquid. In the air the needle must be composed of such substances as will be capable of decomposing that element to indicate polarity. It is a singular fact that those rocks which contain manganese combined with iron ore are the most magnetic, and will preserve longer their polarity.

CHAPTER III.

ON THE REDUCTION AND FORMATION OF METALS BY ELECTRO-MAGNETISM.

When metals are observed in rocks and in veins, which is of common occurrence in mineral districts, persons are too apt to think that such metallic substances have been produced by intense heat, similar to that applied in smelting works. Such an idea arises from the habit of our looking at metals as the production of our ordinary artificial process of reducing minerals, and not to any cause that can be assigned for this being the only mode of their formation.

When we make a casting of any metal, even the most fusible, we find great difficulty in getting it to take the minute impression of the mould, owing to the great heat necessary to give the metal the required looseness and pliancy. The liquid metal has a considerable amount of cohesion, which tends to make it form into large drops, like that observed in quicksilver; which drops cannot be reduced without intense heat to destroy its cohesion. Besides, the substance which forms the mould must not only be capable of enduring a very high temperature, but sufficiently porous to allow the air to escape, otherwise it cannot produce a smooth face.

The native metals which are found in mineral deposits are often enclosed in quartz; but on whatever substances they may be, they present the exact impression, even the most minute cracks or striæ of the mould. Nor are the substances on which such metals are produced always confined to those that resist intense heat; on the contrary, native copper and silver have been found deposited on timber, and decayed leaves in old mines; and this during their immersion in water. It is therefore very evident that the ordinary process by fusion is not capable of fulfilling the above conditions of the metals in the mines: but it is identical with those formed in the humid way by electro-magnetic action.

In speaking of metals, we should not forget that a great number of them are found not as solids, but in solution in the rocks. Indeed there is no rock *in situ* that is not found more or less saturated with mineral waters.

Iron is abundant almost in all mineral waters.

Copper is found in solution in all the copper mines in Europe and America; and a large proportion of copper is obtained by the introduction of iron to precipitate the metal from its solvent in Anglesea, Spain, New Brunswick, &c.

All metals are capable of remaining in solution as well as in their solid state.

Platinum remains in solution with one part of nitric to two of muriatic acid.

Gold is soluble in nitro-muriatic acid; and held in solution, also in caustic alkali.

Silver is soluble in nitric acid, and in sulphate of iron.

Nickel dissolves in nitric acid, and alkaline menstruum.

Zinc, *Lead*, and in a word, all metals, are susceptible of remaining in solution as well as in a solid state; therefore we should not consider that the metals must necessarily be solid in their original state. The oxides of metals and of cobalt dissolve in large quantities in caustic potash, and may be diluted with water, without a separation of the oxides. Caustic potash is also the natural menstruum of siliceous substances. Indeed there is some difficulty in preserving some metals, especially iron and zinc, in their metallic state, in consequence of their great affinity for oxygen; and those metals only which possess but little

affinity for this element, such as platinum, gold, silver and copper, are found precipitated and preserved amongst the debris of rocks in their metallic state.

When we subject any metallic solution to the action of the magnetic current, the metal will be reduced, in different states, according to the strength of the solution and the intensity of the force employed.

In order to ascertain experimentally what are the circumstances which tend to produce these conditions, we have only to procure a galvanic battery and connect it with two platinum poles, which we place in a vessel to serve as the precipitating trough. In this trough we place a saturated solution of a metallic salt—for instance, copper—when on examination, if the battery possess but feeble power, we shall find that crystalline copper will be deposited; if, however, we dilute this solution with twice, thrice, or four times its bulk of water, the metallic deposit will assume a very different aspect: it will then be aggregated in a flexible state, or a reguline deposit. If we now dilute this same solution to an infinitely greater extent, the metal will still be reduced, but in the form of a very fine black powder.

Almost all metallic solutions may be substituted for that of the sulphate of copper, and the experiment will show nearly the same result, namely, that the strength of the metallic solution influences the nature of the deposit.

If we examine the converse of the experiment, and take a solution of sulphate of copper, and use successively, first, one very small battery, then two or three batteries arranged in a series, and lastly, a very intense battery, we shall find that with this self-same solution we can obtain by these means, first, a crystalline, then a reguline, and subsequently a black deposit.

The above variable state in which minerals are deposited by the battery is of common occurrence in mineral veins; and even the same vein presents large and small crystals, and often of variable composition, within a very small compass. We also find the crystals which had formed the nucleus of one variety disappear, and the cavity left become filled with a different substance.

The application of the agency of fire to form such crystalline deposits, is totally inconsistent with the observed facts; whereas

a magnetic or galvanic current passing through the solutions, is capable of imitating such productions, not only those of the mineral veins, but also of all the operations of nature disclosed by geology.

In order to understand how the metals are reduced from their solutions by the agency of a galvanic current, let us take a battery, and observe the actions going on. In placing a plate of zinc in water, and allowing it to be immersed in it for a long period, it becomes coated with an oxide; but if the water be diluted with sulphuric acid, the oxide will be dissolved, and the zinc will continue to present a clean surface to the oxygen of the water, until it is entirely dissolved, provided there be a sufficient supply of that element present.

The above chemical action is however comparatively feeble. This feebleness of action appears to arise from the want of another power to take away the hydrogen evolved during the decomposition of the water by the zinc. If we place another metal having a less affinity for oxygen than the zinc in the same vessel, and connect the two by a copper wire, the action is considerably increased, and the hydrogen evolved from the decomposition of the water is apparently conveyed from the zinc by means of the connecting wire, and finally escapes from the surface of the plate which forms the negative. And it has been experimentally proved that the greater the facilities by which the hydrogen is made to evolve from the negative plate, the greater is the action on the zinc or positive plate.

The positive plate may be considered as the fuel of the battery, and the connecting wire, with its negative plate, the flue and chimney of the battery. If we increase the draft of the chimney for the escape of the decomposed air, the greater is the supply of oxygen to the fuel; if we break the connexion between the fire and chimney by shutting the flue, we check the combustion; and such is the nature of the battery *.

* The electric light, heat, or motive force are governed by the same principle of action, viz. for any given result produced, a given quantity of some material must be consumed, or changed, in the battery. As it is necessary to burn a certain quantity of coal to produce the required amount of steam and horse-power in a steam-engine, so it is necessary to effect a similar change in a certain quantity of the elements of a battery to produce any electro-magnetic force. According to experiments made by Mr. Hunt, a grain of zinc consumed

In order to increase the intensity of the battery Mr. Smee introduced platinized silver, which possesses the singular properties of evolving, or rather liberating the hydrogen with great facility; hence the draft is thus increased, and consequently the combustion of the zinc accelerated. The direction of its current is from the positive to the negative plate, and it is the positive plate that commences the action and causes the decomposition. The metals in solution are reduced into their metallic state in the decomposing trough of the battery on the negative plate, *i. e.* the plate which evolves the hydrogen. The hydrogen in oozing out of the negative plate seizes upon the oxygen of the oxide of copper, and forms water, whilst the metallic copper is thrown down on the plate; and as long as the strength of the metallic solution is kept up and remains in contact with the plate, the hydrogen issuing out will continue to liberate the metal from the oxygen, and the reduced mineral will present the appearance of a lateral growth from the plate, analogous to an efflorescence or radial crystallization.

Whilst the above action is going on, on the negative plate, a contrary effect is taking place on the positive. If the positive plate of the decomposing trough be copper, as is always the case in reducing copper solutions, the acidulated water in contact becomes decomposed by the oxygen uniting to the copper, the quantity of copper reduced at this plate being about equal to that formed on the opposite plate, and thus the strength of the solution is kept up, according to the system of electro-plating; the effect being due to one constant direction in which the hydrogen moves, uniting with the oxygen at one pole, and becoming liberated from it at the other.

We have already observed that the crystalline character of the reduced metal depends on the intensity of the current and the strength of the solution. If the current be very intense, causing the evolution of the hydrogen from the negative plate, it forms a fine black powder; if none evolves, the metal is generally thrown down in its crystalline state.

The quantity of electricity passing influences the state of the

in the battery induces an electro-magnetic force capable of lifting 80 lbs. 1 foot high; whereas, in the boilers of the Cornish steam-engines one grain of coal produced steam-power capable of lifting 143 lbs. through the same space.

crystals, for there are varieties of deposit, one of which arises from a deficiency of quantity in relation to the strength of the solution; the metal is like an aggregation of sand, the particles having no cohesion or consistence. In this state the plate of metal is in the utmost state of brittleness, and this is produced by too small a quantity of electricity in a strong metallic solution. Another variety of the crystalline state of metals arises from a large quantity of electricity in relation to the size of the plate; thus, by using a very large positive pole, connected with a battery of feeble intensity, and by employing at the same time a strong solution, large crystals, possessing the utmost degree of hardness, will be thrown down. In a word, innumerable varieties may be formed by different degrees of force and solutions.

Comparing these facts with those observed in metalliferous deposits, we find a very striking coincidence; and when we apply similar laws and orders of deposition to mineral veins and crystalline rocks, the problem of their formation is easily solved without having recourse to the igneous theory. Indeed the subterranean action alone, without the aid of any artificial battery, is sufficient to produce the effects above explained, as proved by Mr. Fox some years ago.

CHAPTER IV.

ON HEAT PRODUCED BY THE ELECTRO-MAGNETIC OR GALVANIC FORCE.

THE next phænomenon which a battery displays is the power of heating substances according to the amount of current which is actually passing, and the resistance which they afford to its passage; and in this way the most infusible metals, as platinum, palladium, gold, copper, iron and steel, may be instantly melted.

Conducting liquids may be heated in a similar manner. This fact may be seen in a great variety of ways: dilute sulphuric acid may be made to boil in a siphon connecting two vessels, in which the poles of an extensive series of batteries are placed. Another mode of showing the same fact is to take a piece of

string and moisten it with acid, connecting the extremities with the poles of a series of galvanic batteries, when it will begin to smoke, and become charred from the heat produced.

The next property which a battery displays is its power of igniting metallic or charcoal points when joined to the two ends of the battery, and held so that they barely touch; a light is then exhibited equal in brilliancy to that of a little sun, as observed in the electric light. The spark seems to depend principally upon a combustion of fine particles of metal, or, when charcoal or hard gas coke is used, upon little points of it flying from one pole to the other; so that one pole wastes away and the other increases, till the flame becomes quite encased in a mass of carbonaceous matter. This flame is repelled or attracted by a magnet held in its vicinity, and exhibits the phænomenon of the polar lights. Heat is, indeed, one of the effects of chemical action; and though we might by a fallacious reasoning be led to assert that chemical action is the effect of heat, a very slight examination will show the absolute futility of such ideas. In fact, we have no heat of which the cause is known, but that which is derived from, and proportionate to, chemical action.

A body of water may with propriety be considered to be derived from the ocean, or primary liquid; but we could not be justified in attributing a similar origin to a fiery matter, or in stating that melted substances issuing out of rocks must be the produce of an incandescent nucleus. We have only three primary divisions, viz. solid, fluid and gaseous: we have no igneous liquids in a natural quiescent state; a hot or melted substance is merely the effect of decomposition.

The term heat, it is true, implies the sensation which we experience on approaching a fire; but in the sense it bears in physics, it denotes the cause of that sensation. We should be greatly deceived if we referred only to sensation as an indication of the presence of fire. Many of those things which excite in our organs, and especially those of taste, a sensation of heat, owe this property to chemical stimulants, and not at all to any igneous effects.

There are many chemical agents which, from their corroding, blackening, and dissolving or drying up the parts of some descriptions of bodies, and producing on them effects not generally

unlike those produced by heat, are said, in loose and vulgar language, to burn them, such as the "gossan" of a lode, or coal charred by being in contact with other substances; and this error has even become rooted into a prejudice, by the fact that some of these agents are capable of becoming actually and truly hot during their action on moist substances; similar to the effect of cold water poured into sulphuric acid, or fresh burnt lime.

Fire, or the combustion of inflammable bodies, is nothing more than a violent chemical action attending the combination of certain substances with oxygen.

One of the arguments brought forward in support of the igneous theory, or central heat, is that it is found, by experiments in mines, that the heat increases with the depth, and that hot springs and mineral waters are found in all countries. Had this increased temperature proceeded from the radiation of an incandescent nucleus, we should have a more uniform variation as we descend. In South America, where I have made a great number of experiments, the variations in the degrees of heat were not only very irregular and confined to particular parts in the rocks, but also in some instances the temperature was *found many degrees lower at a greater depth than near the surface.* This is easily accounted for by the variable nature of the chemical actions which are going on in the rocks. Parts of the rocks in deep mines, which are found intensely hot at one period, are at another time found at a very low temperature.

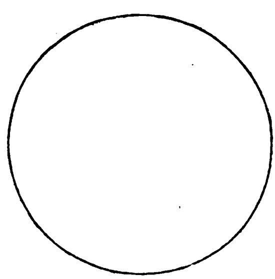
That the action should be greater in depth, generally speaking, than near the surface, is a reasonable supposition; but we have no proof of any intense heat without oxygen, or at least chemical action. I remember an explosion accompanied with flames, and which shook the earth over a large area, arising from a sudden shower of rain falling on a large heap of iron pyrites, which had been exposed to the atmosphere and had undergone decomposition. All we require to account for the subterranean heat is a current circulating within the crust of the globe, acting chemically and mechanically on those elements which constitute the crystalline film.

It is the opinion of some geologists, that the globe was originally in a state of igneous fusion, and that as this heated mass

began gradually to cool, an exterior crust was formed, first very thin, and afterwards gradually increasing, until it attained its present thickness, which they calculate as amounting to sixty miles. During this process of gradual refrigeration, it is supposed that some portions of the crust cooled more rapidly than others, and the pressure on the interior igneous mass being unequal, the heated matter, or lava, burst through the thinner parts and caused high peaked mountains. The same cause they allege produces volcanoes.

According to this theory, we live upon a thin crust enclosing matter in a state of intense heat, which in particular districts agitates the earth in its pressure to escape, thus causing earthquakes, or occasionally bursting forth and producing volcanoes.

The thickness of the spherical film within the greatest limits of our observations, say from the top of the Andes to the greatest depth of the ocean, is so insignificant compared to the diameter, that it is barely equal to a faint scratch on an artificial globe of three feet diameter. This relative proportion of the observed effects to the assumed conditions is seldom pressed on the mind when questions of disturbances are brought forward.



The black line of the above circle represents a thickness of fifty miles, and we are not able to examine one-tenth of it.

The arguments adduced for such a doctrine are the following:—

First. That the form of the earth is just that which an *igneous liquid* mass would assume, if thrown into an orbit with a motion similar to that of the earth; as if an *aqueous liquid* under similar circumstances could not produce the same effects.

Second. That it is found that heat increases with the depth in mines; thus inferring that there must be fire to produce heat;

whereas it is proved by experiments that chemical action is the immediate cause of heat.

Third. They likewise argue, that the peculiar appearance of *lavas* all over the world indicates that they proceed from a common source. These indications are merely that of a rock *altered by a solvent*, and that solvent, be it igneous or aqueous, is governed by the laws of chemical action, and therefore no argument in support of central heat.

Finally, they contend that on no other hypothesis can we account for the change of climate indicated by the fossils. In another chapter we shall endeavour to show an ample cause for the latter.

Not only is the above doctrine of central heat unsupported by the arguments brought forward in its favour, but the consequence of such an igneous nucleus according to the laws which regulate the circulation of heat through fluid bodies, would be, that the crust of the earth, instead of increasing in thickness, would melt *altogether*, even were it two hundred miles, much less sixty. A cold crust and an incandescent nucleus are incompatible, and contrary to the known laws of terrestrial physics.

It is without doubt one of the most dangerous errors in any science to attempt to allow mathematical refinement to usurp the place of careful experiment; and it would not be difficult to point out many instances of the injury which physical inquiry has sustained from the too-prevalent reliance upon the supposed power of mathematical investigations to alleviate the toil of inductive research; thus too often substituting the laws of geometry for those of physics, and leading the mind completely astray from the legitimate effects of the latter.

If we admit the well-known existence of subterranean currents, and that these exert a slow decomposing power, like that of the voltaic battery, we have a sufficient power for our purpose. In the first place, we have a mechanical tension on the consolidated parts of the rocks, by the linear action of the currents passing through them; and should the intensity of the currents be very great, fractures would ensue, more or less at right angles to the direction of the force. These fractures would admit air and water, and thus produce intense heat, by the avidity with which the

metallic nature of the bases of the earths and alkalies combine with the oxygen. As all the substances which constitute the crust of the globe are found in *solution* as well as solid, saturated throughout the rocks, and to such a degree sometimes as to issue out and form springs, and judging from the violent effects on a small scale which we are able to produce by experiments, a heat would be engendered quite adequate to occasion all that takes place in volcanic eruptions. It is a fact, that nearly all active volcanic groups are within a short distance of the sea; and even those that are not so, have subterranean channels of water. It is a well-known fact in South America, that fish are commonly thrown out of the volcanoes; and some of the eruptions consist entirely of mud or muddy water. The sudden fracture, as well as the rapid expansion of the gases, would produce a vibratory jar, which, being propagated in undulations through the rocks or external crust, would give rise to superficial oscillations, and thus cause earthquakes and subterranean thunder.

CHAPTER V.

THE EFFECTS OF THE ACTION OF THE NORTH AND SOUTH POLES OF THE GLOBE ON ALL SUBSTANCES WITHIN THE SPHERE OF THEIR INFLUENCE.

From a consideration of the general facts that have been stated, it will be sufficiently evident that the earth acts upon matter in the same way as if it were itself a magnetic battery; or rather, as if it contained within itself a powerful magnetic axis lying in a position coinciding with its axis of rotation.

We have already observed that the north pole of the earth is the absorbing or positive end of the axis, as the currents are moving towards it, therefore the pole of decomposition; and the south end the negative pole, *i. e.* the pole of recomposition. Provided these poles be connected by a conducting fluid, an action would ensue; and in consequence of the oxidation going on at the north pole, there would be a tendency in the element to move towards it.

The ocean may be considered as that conducting element, its composition being peculiarly applicable for the purpose. The component parts of the sea, in addition to pure water, are muriatic acid, sulphuric acid, fixed mineral alkali, magnesia, sulphate of lime, and various other substances held in solution, and this reaches from pole to pole.

The great currents of the Pacific, Atlantic and Indian oceans come from the south pole and proceed towards the north. These currents are subject to numerous modifications, in consequence of the obstacles presented by the land to their passage. The eastern coast of South America, and the western coast of Africa form the boundary to the Atlantic ocean; the general movement of which between the above is in a north-west direction, until it enters amongst the West India Islands and the Gulf of Mexico, where it forms the Gulf-stream, from which point it turns towards the north and north-east near Newfoundland. After passing the latitude 40°, it spreads itself and moves more slowly, until it meets the British Islands. By these it is divided, one part going into the polar basin, along the coast of Norway, whilst a portion returns through the German ocean, forming a whirlpool in the Bay of Biscay. This volume of heated water mitigates the cold of the higher latitudes on the west coast of Europe. The Pacific ocean has a corresponding current from the south, whose temperature affects the climate of the South American coast.

Another interesting question connected with these general northward currents is the fact, that within the north polar region the fruit of trees which belong to the torrid zone is every year deposited, and also on the western coasts of Ireland and Norway; on the shores of the Hebrides are frequently collected seeds of plants the growth of Jamaica, Cuba, and the neighbouring continent. The most striking circumstance, perhaps, is that of the wreck of an English vessel, burnt near Jamaica, having been found on the coast of Scotland. From the account of Captain Parry, it appears that there is also a great quantity of timber cast by the sea upon the northern coast of Spitzbergen. Timber is found floating in large quantities in the north polar seas, much of which is thrown ashore on the northern side of Iceland; some appearing to be the growth of Mexico and Brazil.

Ice is fallen in with much sooner in sailing towards the south, than it is in approaching the north pole. The dry lands or the large continents are more or less *pointed towards the south*, whereas the northern parts are ragged and crowded about the northern pole.

The pyramidal terminations of the great continents are frequently repeated on a smaller scale, not only in the Indian ocean, in the peninsulas of Arabia, Hindoostan and Malacca, but likewise in the Islands of the Pacific.

The tides are great waves propagated from the south, along the great valley of the Atlantic, and the coast of the Pacific ocean, proved by daily observations.

Bottles thrown over Cape Horn have been picked up on the coast of Ireland, and on the Pacific side, carried up to the Gallapagos Islands, and the coast of Northern Asia.

When the configuration of a coast opposes the progress of the tidal waves from the south, they reach to thirty feet in the Red Sea, about twenty-two at Panama, fifty at S. Malo, and seventy feet in the Bay of Fundy. Isthmuses running east and west, with open seas to the south, and contracted on the north, have high tides on the former coast, and scarcely a perceptible tide on the latter, as observed in the Red and Mediterranean seas, at Suez, and in the Pacific and Caribbean seas in the Isthmus of Panama. The curve of the African coast near Fernàndo Po is repeated on the coast of the Pacific, nearly on the same parallel; both bend from N. and S. to N.W., the stream having the same effect on each until it is deflected and quits the shores in a N.W. direction. The velocity of this stream appears to be about ten miles per twenty-four hours.

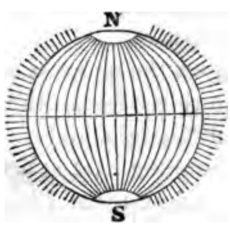
CHAPTER VI.

ON THE POLAR, RADIAL AND EXFOLIATED STRUCTURE OF THE CRYSTALLINE ROCKS.

NOTWITHSTANDING the apparent irregularity of form and undulation of surface visible in the dry lands, yet a careful examination of the *internal* structure of the primary base, shows most distinctly a phænomenon of order as beautiful as th t

observed in the medullary rays and rings in the trunk of a tree. The cleavage planes in all parts of the world are more or less vertical, and only slightly deviating from the meridian, thus exhibiting the influence of the polar force in the molecular arrangements of the crystalline semi-fluid base. As this active polar force is found diffused throughout all matter, acting chemically and mechanically, it must not only have an important influence on the elementary matter, in the gaseous, fluid, semi-fluid and crystalline state, but also after consolidation by acting through the pores, producing tension and many mechanical disturbances.

The annexed diagram will give an idea of the character of the crystalline structure.



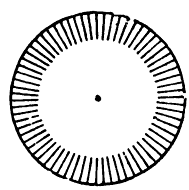
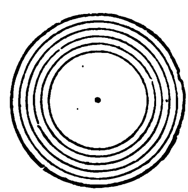



Fig. 1 illustrates the meridional structure, polar grain, cleavage planes, &c., surrounded by radial lines corresponding to the angular direction of the growth of vegetation, efflorescence, &c.

Fig. 2 describes the internal radiated structure, the angular position of the cleavage planes, and also the structure commonly seen in the hematite iron ores, and other spherical crystallizations.

Fig. 3. The exfoliated structure. The three varieties are seen sometimes combined in the mineral kingdom as in the trunk of a tree.

I have carefully examined the cleavage planes in America and Europe, and I have found their mean direction, without exception, only deviating a few degrees to the E. of N., and approaching the structural uniformity of figs. 1 and 2.

On reference to one of my sections of the Andes, Plate VII., it will be observed that the angular position of the cleavage is almost uniform, sometimes radiating in ridges, but generally vertical under the planes, as illustrated in fig. 2, being the normal angular position of the planes. I could furnish numerous sections of gigantic dimensions, to prove by actual observations the symmetrical arrangement of crystals, the systematic aggregation of particles to form masses, not only in South and

North America, but also in Europe, giving ocular demonstration of agencies unceasingly at work, which science with all its refinement has not yet been conscious of. Geologists and naturalists in general know only the visible part, the mere surface, and that very imperfectly; they have hitherto supposed that the acting principle was confined to vegetation, and had nothing to do with rocks.

The continents were not suddenly formed in their present shape; they gradually acquired it by progressive enlargement of the crystalline growth, and successive elevation and depression.

The beautiful internal structure of the coral rocks is produced by growth, similar to vegetation, sponges, &c., and not, as it is erroneously supposed, built by insects. These active operations in the mineral kingdom produce not only solid geometrical figures, but also a great variety of *internal* structures, and may be seen going on incessantly in tropical seas. The animal and vegetable life may be destroyed, but the principle which forms the crystal is indestructible: if dissolved, it will again reappear in all its beauty of order and composition. Minerals however only grow, or are formed, as long as there is a solution of the necessary element present. A loose stone or crystal has no more action than a block of wood; but there is this difference between them, the former will reappear in all its perfection after dissolution, whereas the latter will not. He who would obtain a just and comprehensive view of this subject, must not confine his attention to cabinet specimens, but contemplate them as they are arranged and formed individually and collectively *in situ.* He must watch the progress of natural chemistry and polarity, producing effects which cannot be imitated in our laboratories. In making experiments with the view of imitating the cleavage planes of rocks, we find that the longitudinal structure is produced in the direction of the polar force. The internal linear current causes the magnetic needle to deflect westward in proportion to the intensity of the action. When sea-water is employed, the westerly variation varies from 10° to 15°, hence the direction of the needle and the active cleavage planes do not coincide; and this is found to be the case in all known parts of the world, *i. e.* the bearing of the cleavage planes being generally a few degrees east of the magnetic direction.

This order in the bearing of the cleavage structure has been observed for many years, but for the want of studying the phænomenon more carefully underground, and distinguishing the crystalline planes from sedimentary divisional planes, and connecting the same with general principles in terrestrial physics, these important facts have remained without value.

R

"Since the year 1792," says Humboldt in his Treatise on Rocks, "I have been attentive to the parallelism of beds. Residing on mountains of stratified rocks, where this phænomenon is constant, examining the direction and dip of primitive and transition beds from the coast of Genoa across the chain of Bochetta, the plains of Lombardy, the Alps of St. Gothard, the table-land of Suabia, the mountains of Baireuth, and the plains of Northern Germany, I have been struck, if not with the constancy, at least with the extreme frequency of the directions from south-west to north-east. This inquiry, which I thought would lead naturalists to the discovery of a great law of nature, at that time interested me so much that it became one of the principal reasons for my voyage to the equator. When I arrived on the coast of Venezuela, and passed over the lofty littoral chain and the mountains of granite-gneiss that stretch from the Lower Oronoco to the basin of the Rio Negro and the Amazon, I recognised again the most surprising parallelism in the direction of the beds; that direction was still north-east." See the section of the Andes, Plate VII.

Humboldt wrote the above under the impression that gneiss and schistose rocks were similar to sedimentary beds according to the old theory; hence he confounds the lamination of the former with the divisional planes of the latter.

In Nova Scotia and in Scotland, we perceive that the direction of the bands of the primary rocks and structure of the chains are from south-west to north-east; but the dip varies according to local circumstances, sometimes inclining from the perpendicular to the east and west in the same linear direction.

"The direction of the primitive and transition beds" (gneiss and schist), says Humboldt, "is not a trifling phænomenon of locality, but, on the contrary, a phænomenon independent of the direction of secondary chains, their branches, and sinuosity of their valleys; a phænomenon, of which the cause has acted at

immense distances, in a uniform manner: for instance, in the ancient continent, between the 43° and 57° of latitude, from Scotland as far as the confines of Asia." See Plates IV. and V.

In cutting any of these crystalline bands in an east and west direction, *i. e.* from the eastern to the western coast of the continent of Europe or America, the section will be found in structure similar to that of the Andes described in Plate VII. The lamina or polar cleavage planes being intersected transversely, would on examination show a structure more or less vertical, sometimes leaning to the east, and sometimes to the west; in fact, any east and west section of considerable length would be found to present the same kind of radial structure in the crystalline rocks of all parts of the world. It must be understood, however, that the above remark is confined to the average angular position, because numerous bends and contortions of very considerable extent are frequent in this fundamental structure, and are susceptible of constant changes from the effects of local causes, analogous to that going on in the trunk of an old tree.

On the eastern coast of Ireland, between Waterford and Dublin, the cleavage planes of the gneiss and schist present a mean direction towards the north-east, and are intersected by more recent joints in a north-west direction. It is at these intersections of the old and new structure that the metalliferous deposits of Ireland are principally found, more especially the lead ore: the same structural bearing and metalliferous effect are observed also in North Wales and Scotland.

The cleavage planes of the gneiss and schist run in a north and south direction in Sweden and Finland, the angle deflecting from the perpendicular according to local conditions. The same order of structure is observed in Auvergne, and also in many parts of Spain, and the north coast of Africa.

In the United States of America we find the same meridional structure in all the primary series, *i. e.* a variety of crystalline bands on edge, of various colours and compositions, running north-east. In Virginia, the gneiss, talcose and chlorite slates run north and south, leaning from the perpendicular towards the west. The Boston railway exhibits, by its numerous cuttings in an east and west direction, the general verticality and meridional structure of the schistose rocks for several miles in length.

Along the north coast of South America, in the Atlantic and Pacific, in the Caribbean Sea and the West India Islands, the same structure prevails; and was minutely examined and surveyed by the author, from east to west across the three great branches of the Cordilleras, between the Equator and Central America. See section of the Andes, Plate VII.

We find the phænomena of cleavage planes well displayed on the banks of the Moselle, and also in the roofing-slate districts of Wales.

In an admirable essay published on this subject by Professor Sedgwick some years ago, we find the following observations, showing that this question occupied the attention of this excellent observer:—

"In that variety of slate which is used for roofing, the structure of the rock has been so modified that the traces of its original deposition are quite obliterated; and this remark does not apply merely to single quarries, but sometimes to whole mountains .... In the Welsh slate-rocks we see the cleavage planes preserving an almost geometrical parallelism, while they pass through contorted strata of hard slate, obviously of sedimentary origin .... Crystalline forces have re-arranged whole mountain masses of them, producing a beautiful crystalline cleavage, passing alike through all the strata .... And again, through all this region, whatever be the contortions of the rocks, the planes of cleavage pass on, generally without deviation, running in parallel lines from one end to the other, and inclining at a great angle to the west .... Without considering the crystalline flakes along the planes of cleavage, which prove that crystalline action has modified the whole mass, we may affirm that no retreat of parts, no contraction in dimensions, in passing to a solid state, can explain such phænomena as these. They appear to me only resolvable on the supposition that crystalline or *polar forces* acted on the whole mass in given directions and with adequate power."

In the Geological Report of Cornwall and Devon, Sir H. De la Beche remarks,—

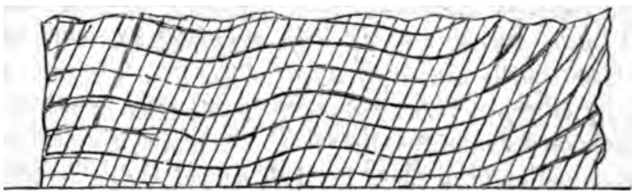
"When we regard the prevalence of the great divisional planes in particular directions crossed by others nearly at right angles to them, producing solids to a certain extent symmetrical,

and consider the mineral modifications which the sedimentary beds have generally undergone since they were deposited, we are led to suspect not only that the lamination planes, commonly termed cleavage, are, as has been supposed by some authors, due to *polar forces*, but also that the great divisional planes have been equally caused by them, as has been considered probable by others. . . . . Although the direction of the present magnetic meridian in the district may be merely temporary, and the proximation of so many great divisional planes to it therefore accidental, still their great prevalence, both in the igneous (crystalline) rocks and sedimentary deposits, in that direction, leads us to suppose that *polar forces* may have considerably governed the arrangements of the component matter of the rocks they traverse during consolidation . . . . If we require a constant tendency of such *polar forces* to arrange the component matter of rocks during consolidation in given areas, we can the more readily account for the frequency of nearly similar directions in the great divisional planes of rocks of different ages."

Hence the crystalline crust of the earth is not a confused shapeless mass of metamorphic and melted rocks, resulting from igneous eruptions, but possesses a structure and arrangement of parts as regular and uniform as any other natural production. It has a general grain, by which any of the crystalline masses will split, and that is from pole to pole, as represented in Plates IV. and V. This meridional grain is produced by the polar arrangement of the crystals in the granitic base causing more or less vertical sheets or plates of mica, talc, chlorite, &c., the influence of which, together with the constant circulation of the polar currents in the direction of the planes, extends to the sedimentary beds, and thus the whole of the surface becomes uniformly cleaved, and exhibits that beautiful polar or meridional structure above described.

Although roofing-slate quarries are so common, and presenting most beautiful natural sections, yet the true character and general angle of cleavage planes are scarcely known to the scientific world. Some imagine that the planes of cleavage are the same as the planes of shale and sedimentary beds, and that the beds have been lifted to their present high angle; whereas

the cleavage planes intersect the sedimentary planes at all angles, thus:



The best roofing-slates run more or less on edge and in a north-easterly direction, and where the old sedimentary seams are obliterated. When the sedimentary planes are lifted so as to conform to the angular position of the cleavage planes, the slates possess great strength and elasticity.

CHAPTER VII.

ON THE GENERAL CHARACTER OF THE CRYSTALLINE ROCKS CALLED "PRIMARY," AND THEIR HIGHLY SATURATED STATE *IN SITU,* AND METALLIFEROUS QUALITIES.

The first and universal fact that presents itself to our notice, when we examine the nature of these formations, is that they contain a very considerable proportion of water, and are often found as soft as clay in depth; indeed the superficial part of these rocks is the driest and hardest portion of the mass. Nothing is more common than mineral and saline springs gushing out of the primary series, and these forming incrustations of mineral matter by precipitation. There is scarcely any spring water which does not contain silica in solution, though frequently in very small quantities.

In South America great streams of siliceous and calcareous matter are seen daily issuing out of the crystalline rocks and forming large deposits; and even common salt is in many places obtained from the saline springs coming out of *granite* and *porphyry*. Rock-salt is found enclosed in porphyry in

Peru. The deposits of rock-salt and the springs of muriate of soda in the eastern Cordillera, succeed each other from Pinceima in the south to the Llanoes de Meta in the north, a distance of about 200 miles in the same linear direction. The direction of the subterranean salt springs, like other mineral solutions, is independent of the inequalities of the surface, or the character of the beds, and may be traced for miles in meridional bands. In England we find the saline springs similarly situated. We may consider Dudley in Worcester as the northern part, and the mineral waters of Cheltenham as the southern; all the brine springs are situated in the intermediate space, and almost in a north and south direction, or at least conformable to the general bearing of the primary cleavage planes or meridional splits. Salt springs issue from the micaceous schists, porphyries, and the granites of South America, together with the sulphate and carbonate of lime.

Siliceous springs are equally abundant in all the granitic and porphyritic formations of the world.

Large trunks of trees and timber in old mines, which have been long under water, have been found silicified in a comparatively short period. Even vegetation contains a proportion of silica taken up by the roots, and crystals have been found within the cells, and often large ones in the bamboo.

There are immense siliceous and calcareous stumps, in their natural growing position, in Chili, Veraguas, in Australia and Egypt; showing most distinctly that the trees became silicified, when in the act of growing, by an excess of silica and lime getting into the soil. The upper part having decayed, the whole forests appear to have been snapped off by the winds nearly at the same time; the brittle character of the stumps causing them to break off like glass horizontally a few feet in height.

In springs predominating in calcareous matter during deposition, the silica becomes aggregated into small round lumps like flints in chalk, forming a nucleus to all the bordering siliceous fluid. A similar phænomenon is observed during the process of petrifaction; trunks are sometimes converted into a calcareous matter, the silica by degrees appears in the centre, from which point it expands, and the lime is forced outwards towards the external margin of the petrified body.

In mines and all subterranean caverns in the primary rocks, mineral springs and the production of crystals are as constant as the growth of vegetation, and these are formed proportionally to the strength of the solvents, as explained in a previous chapter.

The same composition always crystallizes in the same form, unless the conditions of the crystallizing body are altered. It has been shown that each particle of a crystalline body has certain points called "poles," which possess definite properties, somewhat analogous to the opposite functions of the roots and leaves of a tree, being two distinct points diametrically opposite in the greatest activity of converging and diverging actions. This polarity of the particles of matter has been already referred to the influence of terrestrial polarity.

The animal and vegetable tribes cease to continue the functions of life, and a complete disorganization takes place in the final decomposition, and their respective laws of organization may be destroyed in their embryo by the crushing of an egg or the bruising of the seed; but this is not the case in the mineral kingdom; the crystal being the result of a constantly acting force, which, although bruised, decomposed and dissolved many times over, will again appear in all its perfections. Nothing can destroy the active principle and reproduction of the mineral kingdom.

In the deep recesses of the crystalline film, the subtile powers of polarity always permeate beneath the scene of vegetable and animal life, and a never-ending process is going on, giving form to mineral matter in all their variety individually and collectively, decomposing and reproducing, and perpetually varying the conditions of the aggregate crystalline compound, which we denominate the "Primary series," analogous to that going on within the trunk of an old tree.

Every elementary body, when placed under circumstances which allow of the free movement of its molecules, has a tendency to crystallize, and the slower the action the more perfect, and the greater the magnitude of the crystal.

Water holding lime in solution is colourless and perfectly transparent. Let the water slowly evaporate, and the crystals will appear in their usual form and refracting character. These crystals gradually grow until the aggregated calcareous mass

forms a symmetric figure, the primary form of each individual crystal being a rhomboid prism.

A crystal thus produced may with propriety be called "Primary," as it is formed from the solution of a primary element, like the crystals of chloride of sodium, sulphate of lime, magnesia, &c. from the sea, into definite forms according to exact laws; and the comminuted and decomposed crystals forming clays, sands, &c., reconsolidated by any cement, may be called a "secondary" or "sedimentary formation." Therefore the terms "primary" and "sedimentary" rocks used here, are to be considered in the same sense, having no reference whatever to the time of their formation.

With regard to the interior of the globe below the crystalline film, nothing can be determined from immediate observation, or by legitimate induction from data founded on experiments, nor is the question essential to our inquiry.

Much importance is placed by some on the degrees of increasing temperature found in our mines to prove igneous fluidity in depth.

The greatest depth towards the centre ascertained by us, is the bottom of the ocean, which (within the tropics) is much colder than the surface, indicating that the heat affecting the surface is solely derived from the sun. The few and comparatively insignificant perforations we have made into the crystalline film are confined to those spots containing minerals in excess, and consequently the seats of chemical activity, and where fresh oxygen is brought in contact with substances to which it has a great affinity, and heat generated during oxidation; therefore, even were there an uniform scale of increasing temperature observed (which is far from being the case), it would not serve as data to found such calculations. The majority of the volcanoes produce hot *water*, alkalies, mud, &c. The few forming slags or lava, show clearly that they are produced by some intense local chemical action, and comparatively very superficial. The fact of their only being in action periodically, shows that they depend on the variable state of the earths or mineral basis, and not on the supposed constant internal incandescent fluidity.

In our investigation of phænomena dependent on natural

causes, certain laws of reasoning should inviolably be adhered to. First, no cause should be adduced whose existence is not proved, either by its effects, or by a true process of induction. Secondly, no effect should be attributed to a cause whose known powers are inadequate to its production. Thirdly, no powers should be ascribed to an assumed cause, but those that it is known to possess, according to the laws of terrestrial physics. And finally, no assumed powers should be brought forward to explain effects which are produced by the ordinary powers of nature, which may be, and are daily observed.

If we strictly conform to the above rules, we shall find that the great and various influence of terrestrial polarity enveloping our planet accounts for all geological changes in rocks and on the surface, individually and collectively; whereas we have no positive reason for supposing even the existence of an igneous element in a quiescent state, and much less confined within a hollow and thin semiaqueous sphere. The volcanoes are insignificant pimples when compared to the diameter of the globe. Granting the existence even of an incandescent matter in subterranean caverns, it could not create a solid, but merely the melting of a substance already formed; therefore there is nothing gained by the application of such an hypothesis as the igneous formation of rocks and internal fire.

It is extremely difficult to produce metallic crystals from fusion, and those which are imperfectly formed are produced when in the act of cooling and very slow sublimation; whereas siliceous and calcareous crystals, salts, &c., are not only daily formed in nature from aqueous solutions, but all substances can be crystallized in the moist way, and somewhat rapidly, under the influence of a polar force by artificial means, but not by fusion.

The crystals forming the primary base could never be imitated by fusion, though every other circumstance should occur, and especially those with or without an intermediate prism terminating with pointed pyramids at both ends, which are very common in porphyritic and granitic veins. Those rocks called ancient lava, such as basalt, trap, greenstone, and other variety of the hornblendic series, are of the same aqueous composition as any other rocks; their pores are always more or less filled with water.

All the rocks, the most solid and compact, lose a large portion of their weight when exposed to a strong heat, and many decrepitate; the weight thus lost is mere water. Although heat is employed to expedite the process of crystallization in artificial works, it is not essential for the formation of the crystal. When salts are crystallized, they retain a portion of the liquid not mechanically mixed, but as an essential component, to which their regularity of figure, their colour and transparency are in some instances referrible.

Thus Glauber's salt contains a great quantity of water, and crystallizes in six-sided prisms, transparent and beautiful; expose it to heat, the water of crystallization flies off, the crystal loses its shape and crumbles into white powder. Crystals of gypsum or sulphate of lime are of glossy transparency, and of regular figure; this is due to water: heat them, they crumble into a white powder, well known as plaster of Paris. Such is the aqueous character of the crystals forming the primary base.

Zeolytes lose from 5 to 18 per cent.; compound spar about 45 per cent.; opals from 6 to 18 per cent.; schorl from 7 to 15 per cent.; Brazilian topaz, 20 per cent.; common flint, 5 per cent.; red quartz, 3 per cent.; felspar, from 3 to 10 per cent.; and quartz is often also found hollow and filled with water. In short, water in some proportion seems an essential ingredient in all rocky crystals, and a supersaturation of an alkali will reduce the crystalline into an homogeneous compound, at the ordinary temperature of the internal part of the rocks.

There is scarcely a substance but what is either found in solution, or may be dissolved in an aqueous alkaline menstruum.

The apparent insolubility of quartz gave rise to some of the difficulties which at one time embarrassed geologists; but, as above stated, silica is not only found in solution, but easily dissolved in caustic alkali, and may be obtained like gum-water or glue, perfectly transparent, and of great tenacity, possessing the plastic properties of fine clay. The same plastic character is often found in the felspathic granites in great depths, and especially in the china clay districts.

The ocean may be considered as the primary menstruum or mother-liquid from pole to pole, keeping the mineral crust of the globe in a constant state of saturation and active cry-

stallization, as slightly sketched in another chapter, being a weak compound of all the elements in solution through which the polar force permeates from the diverging to the converging focus of activity. From analogy, and according to many experiments made with a battery in connexion with a globe of ten inches diameter, crystallization commences at the diverging or hydrogen pole, and these crystals form lines until they extend to the converging or oxygen pole in symmetrical meridian lines, and thus producing a polar grain from pole to pole. The extreme ends of these linear crystalline growths oxidate as they approach the north or pole of convergence; and as fast as this end is oxidated and dissolved, the same amount of new crystals is formed at the diverging poles, and both crystals and water are propelled from the hydrogen to the oxygen poles, or, in other words, from south to north; and thus producing the northward movement which we observe in nature, that is, the constant northerly currents of the Pacific and Atlantic oceans, and the northward action of the polar cleavage of the primary rocks, together with those polar effects we observe in mineral veins.

In all the primary rocks in every part of the world, where they have been carefully examined, we recognise in every crystal, and the compound crystalline masses, the action of these constant forces of polarity and chemical affinity, giving to each mass a polar grain, and to every crystal a definite form and composition in accordance to the general law of action already explained; hence the above may be considered an experimental demonstration of the observed natural truths and totally free from all assumptions, and has been for years as useful in practice as correct in principle, which is the true and proper test of a correct theory.

The principal elementary substances entering into the composition of the crystalline rocks may be considered the following:—

Silica,	Lime,	Carbonic acid,
Alumina,	Iron,	Sulphuric acid,
Magnesia,	Manganese,	Muriatic acid,
Potash,	Fluoric acid,	Nitric acid,
Soda,	Boracic acid,	Water,
	Oxygen and Hydrogen.	

The aggregated crystalline compound consists of the above in

a state of gaseous fluids, semi-fluids, and solids; the solid elements being in different stages and degrees of crystallization.

Silica forms	Quartz.
Silica, alumina, lime, potash and soda	Felspar.
Silica, alumina, potash and iron	Mica.
Silica, alumina, magnesia and iron	Chlorite.
Silica, magnesia and potash	Talc.
Silica, alumina, magnesia, lime and iron	Hornblende.
Silica, alumina, magnesia, potash and iron	Schorl.
Lime and carbonic acid	Carbonate of lime.
Lime and fluoric acid	Fluor spar.
Lime and sulphuric acid	Sulphate of lime.

&c. &c. &c.

Besides the above ingredients, there are also disseminated in the crystalline rocks, or in a state of saturation, all the known minerals, and these even may likewise be compounds of which hydrogen forms a part.

Hydrogen gas dissolves iron, zinc, arsenic, sulphur, carbon, &c., and from combinations thus formed, we can with facility separate these elements. Such substances may exist in rocks, and in our atmosphere, without our being cognizant of them, and thus supply the required substances for the formation of the aërolites of iron and nickel.

The aggregation of the above crystalline substances constitutes what we call *granite*, and which we necessarily consider as the primary crystalline base of all our known rocks.

Numerous names have been given from time to time to the different kind of granites, but it is very evident that such distinctions can only be governed by the predominance of some, and the deficiency of other, ingredients in the compound.

In order to have some idea of the mineral character of the granitic base, as observed in both hemispheres, we shall enumerate the following:—

Quartz, felspar and mica	Common micaceous granite.	
Quartz, felspar and talc	Talcose	ditto.
Quartz, felspar and chlorite	Chloritic	ditto.
Quartz, felspar and hornblende	Hornblendic	ditto.
Quartz as homogeneous compound	Basalt, trap, &c.	ditto.
Quartz with crystals of felspar	Porphyritic	ditto.
Quartz and talc	Quartzose	ditto.

&c. &c. &c.

Felspar in general constitutes by far the largest part of the granite, and is the active agent of decomposition, owing to its alkaline character, and is the principal agent by which the silicates or compounds of quartz and metals are separated in the laboratory of nature.

When silicates, mica, talc, &c. predominate, these crystalline flakes are gradually drawn or grow out as it were from the granitic base into a fibrous or laminated structure, the respective ingredients (as explained in another place) become formed into thin, vertical, parallel plates, known as cleavage or polar structure; and sometimes into elongated fibrous bars, well known to quarrymen who are accustomed to split granite and slate rocks according to the grain. This change is always found in meridional bands, as already explained, proving distinctly the influence of polarity in the molecular arrangement throughout the compound.

This elongated structure or laminated granite is called gneiss, being identically the same chemical compound as the granitic base. The transition of the crystalline aggregation to the laminated structure is necessarily insensible, the action being like a simultaneous polar growth of the respective varieties of granites northward; hence a micaceous granite produces micaceous gneiss, chloritic granite, chloritic gneiss, &c., as seen in the section of the Andes.

Schist and clay-slate form the external termination of the great granite masses, being their respective oxidated crusts; branches and leaves as it were of the great granitic trunks. The mica granite passes first into gneiss, then into mica schist, by an almost imperceptible gradation, as illustrated in Plate VIII.

This slaty portion of the primary is often confounded with sedimentary rocks, and from its constant state of activity, it frequently obliterates sedimentary seams, and cleaves the superficial beds at right angles to the horizon, giving the superincumbent strata a polar structure, as commonly observed in roof-slate quarries and described in Chap. IV. It is the final decomposition of the felspar between the plates of mica and quartz that distinguishes slate or schist from gneiss.

The felspathic granite, especially when supersaturated with lime or potash, never produces the above schistose variety, but

exfoliates along the undulating surface, and changes into brown compact clay-stone, called killas, a compound of silicate of alumina, variously coloured according to the quantity of the peroxide of iron present. This is the general character of the killas of Cornwall, lapping on the granites and porphyries. These clay-slates are seldom schistose.

It is within the limits of this transition of the crystalline base into the oxidated compound that the minerals become principally developed in veins, &c., neither very deep into the perfect crystalline, nor yet far off from its termination into clay-slate. This variety of clay-slate is generally productive in copper and tin, and also in gold and platina, in the auriferous granite districts.

Each series of granite and schist, or granite and its clay-slate, belongs to one formation, and each variety along the line of cleavage is essentially composed of the same minerals variously modified, decomposed, &c. by polar influence, and their individual and chemical affinity; passing by insensible gradation from the base to the slaty structure, in vertical plates, in meridional direction, and finally into massive clay, and subject to constant changes and disturbing local causes.

When the cleavage planes are not developed in the exfoliated and massive variety, there is nevertheless an action passing through their *pores* in the same polar direction as the cleavage planes; and this constant force gives rise to the great meridional splits called cross-courses.

Besides the regular transition of the crystalline base into slate, &c., there are also veins formed interlaminated in the series. Should the base contain a large proportion of silica, quartz veins will be formed within the planes of cleavage, or in the transverse fractures filled by the pores of the rock; if calcareous solutions prevail, carbonate of lime will be formed; and if magnesia and potash, talcose, schist and serpentine veins; these again, united with hornblende and lime, with iron and carbonic acid, will form veins of basalt, trap, &c.: the last varieties are the most active compounds in all rocks; hence the cause of their being called volcanic rocks. The felspathic varieties are found the richest for minerals in every part of the world. The quartzose granite and the homogeneous dark hornblendic rocks are the most unproductive.

When a primary crystalline rock has a moist massive and grey base, and somewhat porphyritic, it is seldom deficient in mineral; but when comparatively dry, with a distinct crystalline grain without a base, it is generally poor in minerals. The metalliferous parts of Cornwall have a porphyritic granite, predominating in characteristic quartz and felspar, which on the surface is partially decomposed or changed into compact brown rock (killas); and the intermediate part is called elvan, being a fine-grained porphyry. The presence of talc and white mica indicates scarcity of minerals, if the proportion be great; however, we must remember that small masses of poor rocks may be found inclosed in the richest series; it is therefore necessary to be guarded before drawing conclusions from isolated cases.

The first fractures produced in any series of rocks are filled with the predominating elements—silica, alumina, lime, &c.; hence we find first veins of granite, elvan, quartz, &c., and mineral veins only become formed after the siliceous and other earthy matter are nearly exhausted in the respective metalliferous bands; we therefore find that the mineral intersects these quartz and porphyritic veins.

As the process in the primary rocks is constant, and the pores and cleavage being always more or less charged with mineral solutions and subject to variable tensions, fractures, &c., the structure of the compound becomes occasionally very complicated, by which cause the phænomena of heaves, splits, veins, &c. are produced, which will be explained in the following chapters.

In Chili, Peru, New Granada, Canada and Norway, grey ore, native copper, and flakes of native silver are frequently found diffused or interlaminated in micaceous schist and gneiss. Gold is also found in flakes in the lamina of the micaceous and argillaceous schist of the Brazils, New Granada, Central America, and California; and the oxide of tin is also found disseminated in schorl granite.

The formation of sulphuretted ores which are sometimes found impregnating porphyritic rocks, as well as in lodes, was formerly considered as scarcely explicable in the moist way, sulphur being supposed insoluble in water; but we find numerous springs issuing out of the crystalline series holding sulphur in solution, sulphuretted hydrogen, &c.

A cubic foot of water may contain about 400 grains of sulphur. Carbonate of lead is soluble in alkali and lime, and may be precipitated therefrom by sulphuretted hydrogen. Lead is more attracted by lime than by other earths, and limestone formations contain lead in preference to other metals.

Pieces of timber have been found in the mines of South America covered with siliceous and calcareous spar, and in Peru and Chili, grey and red silver ore, copper and iron pyrites, are frequently found formed in old workings. What is called by miners "young mundic," is of common occurrence, and is a new crop of sulphuretted ore found forming in old mines in South America and other places: a fresh crop of fine crystals has been found in gold mines like an efflorescence on the walls, and on the rubbish in the lodes, and in some instances sufficiently rich to pay for the labour of clearing the walls and refuse. It will therefore be evident that the mineral kingdom is like the vegetable, moist, and in a constant state of activity; and although this action is invisible to those who are confined to the surface, and so slow as not to be perceptible to the multitude, allowing them to build and live undisturbed; it is, nevertheless, sufficiently active to provide for the wants of all generations, and constantly forming mineral veins from a mere line, or joint, into thick crystalline masses; and these within the reach of our subterranean industry.

CHAPTER VIII.

ON THE PRODUCTION OF GOLD, THE OXIDE OF TIN, AND OTHER METALS, IN THE STREAMS RUNNING FROM THE PRIMARY SERIES OF ROCKS.

THERE are many strange ideas regarding the origin of metals found in streams, such as the gold in the sands of California, Veraguas, Choco, Brazils, Africa, and Siberia, and also the tin in the streams of Cornwall, Devon, and in the Indian Archipelago. Some imagine that they are the produce of large lodes or veins, whilst others fancy that they are the production of me-

tallic showers thrown up by some extraordinary volcanoes at some particular epoch in the history of our globe. Such loose conceptions proceed from persons who have had no opportunity of studying the real character of these deposits *in situ*, and more especially in those countries where such deposits are daily forming from the gradual disintegration of metalliferous granites and other primary rocks.

Gold, platina, and other metals not subject to oxidation, are frequently found in the debris of a certain variety of granites, porphyries, and their respective clay-slates. These productions depend on the *composition* and *structure* of the primary crystalline rocks and the degree of richness in which the metals are disseminated therein, and the internal chemical action by which joints and crevices are becoming gradually filled with metals, or are crystallized in the oxidating superficial exfoliations of the rocks. These superficial productions, of gold and platina especially, far exceed the quantities obtained from veins, and the metals thus extracted are much purer than that produced by the latter. We likewise find that auriferous rocks are much subject to decomposition, and thus producing and liberating their metallic contents in the divisions of the exfoliated surface, and only rarely in great fissures or lodes, like the sulphurets of the baser metals; and even in these rare cases the precious metal is found mechanically mixed in lodes of iron pyrites. This superficial process of metallic aggregation and decomposition in the auriferous rocks is *constant*, more or less, in every region on the face of our globe, depending entirely *on mineral and physical conditions*, confined to no age, nor to any particular zone.

Many have imagined that the Ural gold-works in Russia were lodes, or veins worked underground in the hard rock, like copper and lead lodes, instead of which, they are principally on deposits, *i. e.* on the detritus or shingle accumulated on the slopes of the ridges and adjacent ravines and plains. The only subterranean works carried on there in the compact rock are those confined to small auriferous quartz veins, yielding, if any, but a slight profit. The gold quartz veins are very deceptive, generally speaking, sometimes glittering with gold on the surface, and with large masses in fractures, yet at a few fathoms in depth scarcely affording sufficient gold to pay the cost of extrac-

tion. Yet these very rocks, when left to the natural processes of decomposition and internal metallic aggregation, produce rich debris at their base. Hence no native washer will work in the compact quartz rock for gold whilst he is able to obtain *unwashed* deposits. The most productive gold veins to a moderate depth are the auriferous pyrites, such as the St. Juan del Rey in the Brazils, and Marmato in New Grenada. The former is in clay-slate, and the latter in porphyry: the gold thus obtained is of a low standard as compared to the superficial production from quartz. The banks and slopes of the tributaries of the Sacramento in California are strewed over with the debris of the auriferous rocks forming the Sierra de Nevada; the deposits being enriched by concentration in pools and other mechanical obstacles to the streams of water; and these deposits diminish in quantity, and are coarser in quality, as the acclivity of the mountains increases. This chain of mountains is similar to the Choco in New Grenada, viz. great ridges running more or less in the meridian, composed of immense parallel bands of auriferous granites, gneiss, porphyries, chloritic slates, hornblende, and quartz rocks, intersected transversely by the deep ravines above alluded to, as illustrated in Plate VII. (Section of the Andes).

The gold washings of El Mineral de Veraguas were once very productive, and are still the most important in the Isthmus of Panama. However, like other old gold washings, the accumulated auriferous debris of the hills and valleys have been all washed over; no important gold lodes have been discovered, and the gold quartz veins not being found sufficiently productive to pay cost beyond the surface, the natives relinquished the task, and are now rewashing the old sands together with what is brought down by floods from the flanks of the granitic chain. The gold obtained from these washings is of a large grain in the higher parts of the ravines, and diminishes to a very fine grain down in the plains, and is of a high specific gravity. The natives of the gold districts are generally expert washers, and know the localities where the gold mostly accumulates, and the kind of rocks which produce it. To an European these gold-washing scenes are pictures of misery; the diggers and washers toil and live like the beasts of the forest, feed on the coarsest food, and sleep often without shelter. The great inconveniences attending

the washing for gold, are the necessity of being almost constantly in the water, and the laborious work of removing the large stones to get at the inferior deposit, which is the richest for the precious metal. This kind of work is precisely similar to that carried on in the tin stream districts on Dartmoor, Bodmin Moor, St. Austell, &c., all of which must be done by manual labour. The extraction of the gold from the sand after the auriferous bed has been taken up from under the stones, is easily effected by means of screens, and perforated plates fixed on hollow inclined trunks, with a small stream of water running over. The washing process is easily done by various simple methods, and the light sand is carried away by the stream of water, leaving a black ferruginous substance behind, in which the gold is usually enveloped.

By bruising and washing the most compact quartz in the auriferous granites and porphyries, we detect gold in an impalpable state of dissemination, forming, in fact, a portion of the compound, like the salt in the sea; but it is in the small fissures only, or in the vacuities of the oxidating crusts, that we find the granular or massive gold formed, by the process of crystallization which is constantly going on in all moist rocks.

In the *hard compact* crystalline rocks in depth the gold is never found in grains; it is only detected in a very minute or aqueous state of saturation by analysis, or by very fine grinding and most careful washing; but after the change of the quartzose crystalline into the clay-slate or silicate of alumina, the gold becomes granular, and is deposited in flakes, crystals, &c., in the cleavage and fractures of the rocks. In Gongo Soco the gold is found in the jacotinga formation (ferruginous clay-slate), in some parts sufficiently rich to quarry the rock to obtain the gold disseminated therein. The same has been observed at Morro Velho. The clay-slate in which the lode is formed is often found to contain from 1 to 1½ oits of gold per ton, and where this rock is fractured, rich veins of gold are necessarily formed. When these rocks decompose they supply the valleys with gold sands. The stanniferous granites of Cornwall present similar instances; the oxide of tin forms frequently a component part of the granitic masses, and when such rocks decompose, they necessarily cause rich deposits of tin in the bordering ravines.

The largest proportion of gold is obtained from rivers and

superficial deposits in granitic districts; the quantity extracted from veins is comparatively small, less pure, and depreciating in quality and amount at moderate depths. Gold is always found in its metallic state, almost pure in alluvial deposits, but more or less alloyed, when found in veins with minerals. There are no *ores* of gold, as often very improperly stated. This metal is never found mineralized in nature, but enclosed commonly in iron pyrites, and frequently alloyed with other *metals.* The gold-producing rocks are not confined to particular geographical zones, as formerly supposed, but are found protruding more or less in meridional bands in all countries where the primary series is visible.

All the ferruginous and friable granites, containing yellow mica and pale yellow quartz, which are subject to disintegrate into spherical masses, produce gold in grains during the change. The auriferous granites bordering the Pacific Ocean, as well as those situate in the interior of the Americas, which I have minutely examined, show this effect in a very striking manner. The internal crystalline character of the auriferous granites changes as it approaches the surface by an almost imperceptible gradation into a kind of globular structure, like a coarse conglomerate, as represented in Plate VIII. This section was taken on the banks of the Rio Negro in New Grenada, and is, indeed, characteristic of the generality of the changes taking place during the process of decomposition and production of gold on the flanks of auriferous granites.

In depth we find the usual crystalline aggregation of quartz, felspar, mica, and sometimes hornblende, confusedly mixed; a specimen broken from which, ground to fine powder, will show a trace of gold in an impalpable state, but so light as to render it impossible to detect any appreciable quantity by the mechanical operation of washing. But, as we ascend, we find the crystalline aggregation passing, by an insensible gradation, into a spherical structure (as illustrated in Plate VIII., to which I beg reference); the respective nucleus of each centre of attraction becomes denser and harder than the parent rock by the concentration of the surrounding silica, like the formation of flints in chalk. Each nucleus becomes enveloped by a series of concentric envelopes, which enclose (as this structural change ap-

proaches towards the surface of the rock) an efflorescence of ferruginous mineral, containing gold in grains. These grey compact siliceous centres are called by the native gold-washers in South America the "madres," or mother of the gold, as without these rounded nodules they seldom find sufficient gold in the debris to make it worthy of the labour of washing. The gold, as already noted, is in such a minute state of dissemination in the uniform crystalline base, as to make it almost difficult to detect the mere trace of it; but in the oxidated and decomposed crust the metals become aggregated to different centres, and form into grains, easily caught by the ordinary washing process.

The stony nuclei, as well as the concentric rings, are completely deprived of their original auriferous contents by this process of internal aggregation. After these oxidated crusts are brought down by the torrents, and washed away from the foot, or from the ravines of such mountains, the gold-washers must remove to other localities, or wait a few years until this slow process of nature supplies them with a fresh crop, as they know to their cost that it would be useless to penetrate very deep into the hard rock in search of the metal, as it must have a vacuity or a fissure for its formation.

Friable granites are exceedingly productive of alluvial deposits. The gold deposits of California, as already noted, are precisely of the same character, the quantity of the available gold being limited to the amount of the decomposed debris accumulated in the ravines, with the exception of that formed in the upper portion of the quartz rock. I know of no primary rocks of the above composition of quartz and felspar, and the friable ferruginous granites, with bright yellow mica, but what contain gold.

Gold and tin, if not embodied or overpowered by strong polar substances, such as sulphurets of iron, copper, or other compounds of similar polar tendency, remain in the crystalline base in the disseminated state, and only become developed by crystallizing or efflorescing towards the surface. If mica, talc, or chloritic flakes, happen to be in excess, they will produce a fissile structure, the longitudinal action generated by which causes tension, and consequently a series of transverse fractures

in the more friable parallel and enclosing bands. The surfaces of these internal planes or fissures become gradually coated by the metals the rock may contain, and thus form longitudinal and transverse veins. But if felspar happen to be the predominating ingredient, and this strongly saturated with iron, or any other substance susceptible of rapid oxidation, or if the compound be very friable, the exfoliated decomposition will ensue; the free silica aggregates into centres, the felspar is reduced into clay, the metal collects into grains, disintegration takes place, and the thin, loose, friable surface is gradually washed into ravines; the heavier substances fall to the bottom, and accumulate in pools and other parts of the stream presenting the greatest resistance, whilst the lighter particles are washed away by the torrent. Such is the general character of the deposits of the gold and tin stream washings. These deposits are therefore the product of friable metalliferous rocks, and not derived from lodes. The metallic contents of such rocks can only become available by this process of slow decomposition. The value of these deposits depends on the superficial extent of the metalliferous rocks falling to the ravines and the plains, to receive the accumulation of centuries. It will be easily conceived, that works of discovery, carried into the hard crystalline base to a great extent *beyond the deposits* in such rocks, must prove fruitless; and if such explorations be carried on by men who have no other knowledge to guide them underground than the occasional specks of mineral in the rocks, priany, quartz, &c., their reports would be "kindly and promising" until doomsday, and consequently an immense capital would be wasted away in unprofitable works, and which has been the case in almost every gold mine carried on by Europeans.

Gold has been often found in the tin streams of Cornwall, and is frequently associated with the oxides of this metal in the schorlaceous granites, and in the gossans (the oxidated portion of the lodes), and also in the ravines intersecting the ferro-felspathic rocks of Scotland. When the gold was discovered in the streams of the Ballin valley in the county of Wicklow in Ireland, almost the whole population of the neighbourhood flocked like the Californians, to gather so rich a harvest, and actually neglected at the time the produce of their

fields. Stream-works were established and continued for a few years, and the products left a surplus over expenditure, and some large lumps were found. This, however, was soon lost, as well as another capital added to it, owing to the mistaken notion of the existence of a *mother lode*, whence it was supposed the fine deposit of gold came.

The best miners of the old school were consulted and encouraged this idea; the solid mass was soon intersected by numerous trenches, levels, shafts, &c.; every quartz string was driven through, under the impression of finding the grand source of this wealth, but of no avail; with the exception of occasional grains in vacuities or joints, nothing was found worthy of notice, and the undertaking was abandoned. Yet these same valleys still furnish a small amount of gold annually, and will continue so to do whilst the granitic domes remain subject to decomposition.

The intelligent and real practical Cornish miner, more especially in the stanniferous districts, is getting now so well acquainted with the character of the crystalline rocks, that he knows from mere appearance of a specimen what kind of granite will produce tin. Schorl appears to be an essential ingredient, or at all events, a constant associate of the oxide of tin.

In Dartmoor, St. Austell, and the Land's End, the oxide of tin is in some places so much disseminated through the schorlaceous granite as to render it worth quarrying for the extraction of the tin. All the metals that are found in this disseminated state are always more pure than when in veins. Those elements which produce joints and fractures, and veins in the crystalline base, form the accumulation of the metals in the recesses at the expense of a considerable amount of alloy of mineralizing substances, such as iron pyrites, the arsenical pyrites, &c., consequently metals obtained from veins are never so pure as those procured from the decomposition of metalliferous rocks; when dispersed in the latter they are comparatively unalloyed. It is important to bear this constantly in mind, when we have to consider the merits of such productions in an economical point of view.

The stanniferous, like the auriferous rocks, are often very friable, and subject to disintegration; the felspar decomposes

into clay, according to the character of its component parts; an exfoliated oxidated crust is formed, which is gradually washed down to the ravines, where the several substances are deposited, according to their respective gravities; the oxide of tin, being the heaviest, will occupy the lowest beds in each accumulation. There was a time when the most intelligent old tinners did fancy that these alluvial deposits of tin came from lodes, but, fortunately for our industrial science, such erroneous notions are now almost matters of history with practical men. Some vain attempts have been made to determine the age of this superficial detritus of stream tin, and its associated gravels, but to no purpose; it is like that vague term, diluvium, it belongs to all ages, only more active perhaps at some periods than at others from local and physical conditions. Sometimes we find the tin-stone pebbles, the comminuted quartz grains, and the oxide of tin, left behind on the parent rock, and the decomposed felspar washed away; and this covering becomes so thick, as to prevent further decomposition.

In the Indian Archipelago the same phænomena occur, especially on the island of Banca. This island, with its ridges, conforms in its direction to the Asiatic ranges of mountains, *i. e.* running north-east, and is composed principally of granite, both ferruginous and schorlaceous, the predominance of the former giving it a general red colour. The oxide of tin is disseminated more or less throughout the schorlaceous granite, and is found in beds at the foot of the granitic range, either immediately under the surface or at no great distance below it—the greatest accumulations are mostly found in low situations near the schorlaceous ridges. These deposits are composed of clay of various colours, from pure white to yellow and red. The most productive beds of tin ore have been found near the central parts of the peninsula, at the junction of the districts of Sungiebulu, Klábbet, and Tengá.

The lowest bed is generally of the purest white colour, very light, and adheres strongly to the tongue, like pure clay, on which the ores of tin are deposited in layers, differing in richness and extent according to the locality and quality of the parent rock. Sometimes the tin is found dispersed through the whole of the bed, commencing immediately under the soil, and

increasing in quantity towards the bottom. The schorl in the granite is often seen in black strings, intersecting each other at different angles, and also in elegant needle-form crystals, which renders the granitic mass loose and friable. In some parts the minute particles of schorl are barely perceptible; in other portions this substance is uniformly mixed through the stone, and again the granite changes into a different compound, in which schorl cannot be detected. In all the stanniferous granite rocks the mica is but sparingly distributed, the admixture being quartz, felspar, and schorl in variable proportions. The exfoliated beds formed by decomposition *in situ* on the surface of the granite, consist of fragments of quartz and felspar, with small particles of schorl and the oxide of tin. Sometimes coarse fragments of decomposed granite are seen with breccia, through which the oxide of tin is disseminated. The productiveness of the deposits of the valleys gradually diminishes as the acclivity of the hill increases, similar to gold washings, and thus plainly showing the origin of these alluvial deposits. All persons engaged in such works should never forget this most important fact. These superficial processes of decomposition and deposits are constantly going on in every region of the earth where the primary rocks are exposed to the atmosphere.

CHAPTER IX.

THE DIFFUSION OF MINERALS THROUGH ROCKS.

Rocks impregnated with minerals, as well as the precious metals, are not only of common occurrence in foreign countries, but also well known in England, and have been most fully described by Mr. Henwood in the Transactions of the Royal Geological Society of Cornwall, vol. v. Granules of tin ore are found dispersed through, and form an integral part of the granites of Dartmoor, Kit-Hill, Bodmin Moor, St. Austell in Carclaze, Crowan, Godolphin, and the St. Just districts, and more especially in the pot granite. We find the tin also disseminated through the elvans of the granites and clay-slate.

flanks in all the stanniferous formations of Cornwall and Devon, being in fact a component part of the rock, and not brought in by means of any fissures. Copper pyrites also forms an ingredient in the slate of North Wales, some of the slates of Cornwall (Wheal Music), and in the granite at Wheal Vyvyan, and is indeed very common in the large masses of quartz rock. We find the ore disseminated through these rocks just in the same manner as in the "caple" lodes, excepting that it is more thinly sprinkled. The segregation of these specks of ore, when they are not formed in lines of regular bearing, forms the nodules and other irregular and unconnected masses dispersed through the rocks, as seen in many parts of North Wales, Virtuous Lady Mine near Tavistock, and Ireland. When these rocks happen to be fractured, they favour the linear segregation of the ore within, and thus form veins of clean mineral. This effect can be well observed in the stanniferous granite; where the surface is broken into fissures, the tin ore becomes aggregated in the joints, and in the course of time renders such joints or fractures very productive. These kind of veins containing tin in granite, seldom continue very deep; they are principally limited to the upper exfoliated separation of the friable part from the harder nucleus below. It is only near the flanks that they continue even to a moderate depth in the granite. We find also that the most productive portions of such fissures or lodes are in the valleys and flanks of the granitic ridges. The tender parts, which form valleys by disintegration, indicate the richest portion of the intersecting lodes, *i. e.* the most favourable for the aggregation of mineral substance, and the hard, compact, and high ridges the unproductive. It is the gradually wearing down of these soft and productive bands of granite, that forms the tin-stream deposits noticed in the previous chapter. Many persons, and indeed many of those called practical miners, have an idea that it is the lode that brings in the ore, and consequently they think that they ought to be as rich in the ridges of the granite as in the valleys, or in one part of the lode as well as another, even miles long through various qualities of rocks; and thus lead capitalists into many unprofitable speculations. As, therefore, the productiveness of lodes depends on so many internal conditions, both in the mechanical structure and mineral com-

position of the rocks, and chemical activity from aqueous saturation, as well as on the angular position of the lodes themselves; and as daily experience shows that the same character of rocks assumes very different values in their metallic contents in different districts, from the want of the combined favourable conditions, *i.e.* granites, clay-slates, and their junctions, it becomes necessary to be extremely guarded in drawing conclusions, and nothing short of very long and extensive experience in every description of mineral districts can qualify a person to give a correct report on an unexplored ground.

It is lamentable to see the loose and extremely incorrect reports commonly made by incompetent persons, which lead to so much waste of capital. We frequently observe the term *strata* employed in describing the formation of *granite* in some of our mine-agents' reports, showing clearly that they do not understand the definition of strata or stratified rock, and much less correct reasoning from analogy.

There are also masses of mineral in granite and slate called pipes, carbonas, &c. These are large and long masses of ore, generally in a slanting direction, but sometimes perpendicular like the trunk of a tree, with roots, enclosed in or surrounded by the rock. They are found very oblique in the granite of St. Ives, neither appearing at the surface nor extending far downwards, having both roots and branches, the main mineral trunk being about ten feet diameter in the middle. It often happens also that minerals accumulate in "floors," *i. e.* in the horizontal or oblique joints. To conclude, we may briefly state that minerals grow out of rocks into all kinds of fractures, joints, cavities, &c., and the smaller masses broken from the small veins of the parent rock represent exactly the phænomena of mineral veins on a small scale, in character, contents, and dislocations. We shall enter more in detail on this interesting question in another chapter, and then show that a very slight variation in the appearance and position of rocks indicates different productions of metals, and respective quantities, such as gold, tin, copper, silver, lead, &c., with their compounds.

CHAPTER X.

ON THE UNIFORMITY IN THE ORDER OF THE STRUCTURE AND JOINTS OF THE GRANITE AND OTHER PRIMARY CRYSTALLINE ROCKS.

THE development of the structure of crystalline rocks, by a partial and incipient decomposition, is dependent on the same principle as that by which the crystalline texture of mineral and saline masses is disclosed by the action of a weak solvent. Wherever a large section of granite is exposed to the atmosphere, its surface becomes divided into joints and fissures, preserving almost exact parallelism amongst themselves, thus producing internal forms of cubes, rhombs, and spheroids. When these blocks become much exposed to the action of the elements, they are gradually converted into quadrangular piles, as if built into isolated towers or pillars, or spheroidal masses. These structures and subsequent changes depend more or less on the composition of the granitic rocks. The ferruginous granite exhibits the most perfect spherical concretions; the common granite, especially the felspathic, the cuboidal; the fine-grained granite disintegrates into tabular masses; the schorlaceous granite and shorl-rock often assume the prismatic form, and this is also observed in the hornblendic variety.

The common reduction of the granitic concretions to the spheroidal form, by the action of the elements, is also a property belonging to greenstone, basalt, and other hornblendic and trap-rocks, as observed at Panama, Cauca, Choco, &c.

We find not only globular aggregation of very fine and hard granite, but also the constituent parts of the mass so disposed around common centres, as to form concentric layers, as already explained in the chapter on Gold. These changes may be observed in Corsica, Norway, the Western Isles of Scotland, Brazils, Choco, Panama, California, &c. These nuclei are often found as perfectly spherical as cannon-balls in the gold-washing districts, and have been used by the Turks for that purpose in their batteries.

The spheroidal structure is not confined to the component concretions of the granitic rocks, but is likewise characteristic

of the entire masses, the surface of these crystalline masses being generally of a rounded form or dome-shape, and traversed also by exfoliating subdivisions conformable to the curves and undulations of the surface. We may, from the appearance of the configuration, determine approximately the composition of the crystalline base. The granite is not only traversed by systems of parallel joints, as already stated, but is also capable of being cleft in directions corresponding therewith, so that the masses can be subdivided from the large to the smallest scale, according to the character of the fundamental structure, as described in the chapter on the polarity of cleavage. Large masses of granite may be cloven into cuboids, where the joints are not visible, and thus form blocks corresponding in form to those developed during the action of decomposition. The quarryman from experience can detect the grain in granite, and by boring several holes in the direction of the grain, cleave the granite into regular quadrangular masses. Such is also the case with gneiss and primary slate.

Quarrymen are well acquainted with this fact, and therefore never attempt to split the rock in a line diagonal thereto. The main split lines of the Cornish and Devon granites, like those of other countries, run more or less parallel from south-west to north-east, being in the same bearing as the cleavage planes already described, which, in fact, are the continuation of the same planes. See Plate VIII. This may be considered the polar or longitudinal cleavage of the granite, inasmuch as it splits nearly parallel to the felspathic crystals. The transverse or oblique divisions are symmetrical joints, divided as regular as the felspathic prisms constituting the crystalline base. The granites of Spain are divided in the same manner, *i. e.* in lines more or less north and south, and east and west. We observed the same in France at Auvergne.

In Ireland, in the quarries of Golden Hill, the granite is divided by smooth parallel seams into vertical bands, 3, 4, and 5 feet thick, ranging north and south, sometimes leaning slightly to the east, and again to the west, even in the same band in its longitudinal bearing. These vertical tabular masses become naturally separated again into tabular or columnar blocks of a rhomboidal form. The same effect is seen in Glencullen, also

on the Dalkey coast, the main splits ranging from north to south, inclining slightly from the perpendicular. Hence the granitic rocks are not rude and shapeless masses, as too commonly supposed; the structure and arrangement of their parts exhibit as great a crystalline order as we observe in the aggregation of crystals on a smaller scale.

The innumerable transitions of the crystalline rocks into the schistose structure, in accordance to their composition and meridional direction, are beautifully displayed in South America, and the same may be observed in the Western Islands of Scotland. The nature and order of these transitions, their respective composition and mechanical changes, have been explained in Chapter VII., page 46.

In these transitions of the crystalline into the slaty structure, we find the granitic, the porphyritic or quartzose bands sometimes terminating into wedge-shaped masses, both horizontally and vertically, as illustrated in Plates VIII. and IX.

The various kinds of structure pass so frequently into each other in the same mass, crystalline and schistose, that it is oftentimes very difficult to observe where the one begins and the other ends. As the crystals become elongated flakes, the rock acquires a proportional degree of fissility, and finally a perfect slaty structure; on this account it is impossible to draw a line of demarcation between the two structures, because the transition is imperceptible. This is the case in all the primary districts.

The varieties of rocks predominating in massive clay-slates, and dividing into rhomboidal blocks, principally belong to the felspathic, this structure being observable from the larger masses to the smaller fragments; and their divisional joints and cleavage planes are more or less in the meridian, or slightly north-east. This compound forms one of the richest variety for the production of copper ore.

CHAPTER XI.

ON THE ORDER OF THE SPLITS, FRACTURES, AND DISLOCATIONS IN THE PRIMARY ROCKS; CROSS COURSES AND HEAVES, INCLUDING THE FAULTS IN THE SUPERINCUMBENT SEDIMENTARY FORMATION.

According to the meridional structure and configuration of the primary rocks, especially the laminated granite, the gneiss, and the schist, together with the cleavage planes, and their ridges, as described above, the general appearance of the surface of the globe may be compared to the grain of a fruit, such, for instance, as an orange, a melon, or a pumpkin, having a grain or structure from pole to pole.

Indeed, when we examine the moon through a telescope, particularly in the clear atmosphere of the tropics, the same appearance is visible. We observe most distinctly numerous luminous rays radiating from the pole facing the south, which are seen diverging towards her equator, some of which extend to the northern edge*.

This meridional force, which produces the elongated crystalline masses, fibrous and laminated structure, and cleaving the consolidated sedimentary beds, must necessarily cause a very considerable polar tension.

Let us, for example, suppose a given area were undergoing an elongation by this internal force, as described in Plate XI. fig. 1; should any part of the crystalline compound not possess sufficient tenacity to allow it to extend, fractures would ensue, and these would take place more or less transversely to the direction of the force; the nature and number of these ruptures would depend on the variable state of the mass. Should they contain subordinate channels of unequal elasticity and variable width, splits would occur longitudinally or diagonally to the grain, according to the direction of the least resistance. That the rocks are elastic, and subject to numerous contortions

* The bright polar focus of the moon is considered a volcano by the Plutonists, and the radiating rays streams of lava! It requires no ordinary stretch of the imagination to suppose such conditions without causing some awful catastrophes.

and undulating movements, capable of being bent and elongated without ruptures, is now so well known as not to require comment.

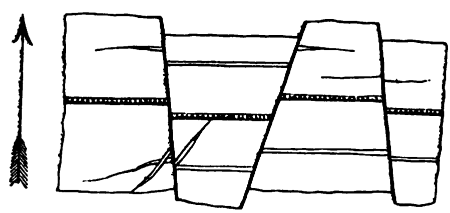
We have, therefore, the following series of lines, figs. 2 and 3, as necessary consequences of the polar action permeating the series, viz. north and south splits, and east and west fractures, varying respectively from their true bearing according to local conditions. These again change their original direction owing to the constant action of a similar nature going on in the subordinate bands, thus giving rise to undulations, dislocations, and numerous other disturbances, which destroy in time the continuity in the order of the sedimentary beds. These great lines are well known to miners, quarrymen, slate-men and colliers, in every part of the world; the first as cross-courses or main faults, and the latter as the east and west lodes and cross faults. These two great divisional lines are observed in Chili, Brazils, Peru, New Grenada, Panama, Mexico, North America, England, and on the Continent.

The sides of the great meridional splits are sometimes found beautifully grooved and polished for immense extent. The masses of quartz broken off, or the quartzose face of these divisions occasionally seen in an escarpment, present the appearance of fluted marble. Such grooves and polished surfaces are very common in the primary series, and are sometimes attributed to the effects of ice or avalanches, &c. brought down from higher regions along the valleys. However, such ideas have been formed as loosely as those which attribute hornblende veins and other black rocks to volcanic eruptions. We do find occasionally coarse grooved sides in deep ravines, which have been produced by the friction or attrition of masses of matter carried down; but these effects are as different from those polished striæ seen on, and *within*, primary and other rocks as the sedimentary planes are to cleavage planes. The sides of the great flookan cross-courses, main faults, or the great meridional splits, are invariably grooved and polished, from the effects of the longitudinal movements of the parallel masses, which cause heaves or dislocations. The striated polished sides of the polar splits of South America vary from 10° to 30° from the horizon, rising towards the north, and are seen not only along the sides of ex-

tensive ridges, but also for many fathoms in depth within the primary series.

Similar meridional splits with polished and grooved sides are seen in Mexico, in the United States (in the coal-beds of Blackheath), and also in Cornwall and other places in England. These primary splits and fractures have broken the sedimentary beds into various fragments of somewhat rhomboidal form, according to the obliquity of the tension and resulting splits and fractures, as shown in Plate VI.

The splits and fractures, and the crystalline mass being in continual motion by the constant action of the subterranean molecular force, produce great disorder in the general structure, and cause dislocations (called *heaves* by the miners). These are the effects of the horizontal or diagonal motion of the individual strips of rocks between the splits from their original position. The great *heaves* are produced by the northward action of the rocks between the polar splits, as shown in the following sketch.



These dislocations have created great discussions, and have caused very opposite opinions, owing principally to the impossibility of restoring the continuity of *all* the fractures on both sides of the splits. A very little reflection must show that such an agreement in *all* the fractures could not be expected. In the first place, the ruptures across the splits would necessarily take place in the direction of the least resistance, be that in a direct line or not; it does not follow that it should be straight across the split. If, again, we consider that the rocks are exposed to the continual action of the polar force, and therefore subject to a slow movement northward, there would necessarily be fractures taking place periodically in the same masses, *i. e.* when the "heaves" are only 1, 10, 20, 30, 50 fathoms; how then would it be possible to restore the continuity of the whole series of

fractures? It is well known, and can be proved, that the fractures have occurred and have become forced open and filled at different periods. It is like attempting to refit pieces of ice, after having been broken and subjected to repeated movements and undulations, and reunited again by repeated freezing, as to try to restore dislocated masses of rocks in the primary base.

When we consider the semifluid nature of the masses, and their permitting a continual molecular action through their pores in the meridian direction, like the current of sap in a living tree, and also supplied by other elements by means of the conducting fissures, we need not be surprised that the sides of the fractures cannot always be refitted; their ruptured parts are altered by the chemical action in a very short time; the south sides of which are often seen penetrating into the northern by a new cleavage formed subsequently to the filling of the cracks, as represented in Plate IX.

Miners are well aware that the sides of veins often bulge out in defiance of all mechanical resistance; it requires a considerable practical skill to keep them open to extract the mineral, particularly in very wet ground. When the *splits* happen to be in a *north-west direction*, the masses of rocks on the *western side* are generally forced *northward* more than those on the eastern side: if the *splits* be towards the *north-east*, the *contrary effect* takes place; that is, in real *heaves*, because a great number are called "heaves" that are only apparent. See

Fig. 1.

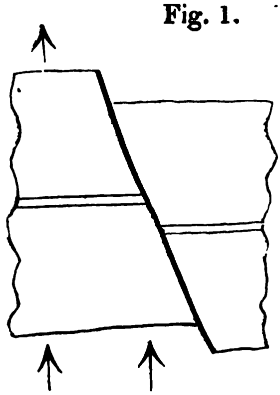
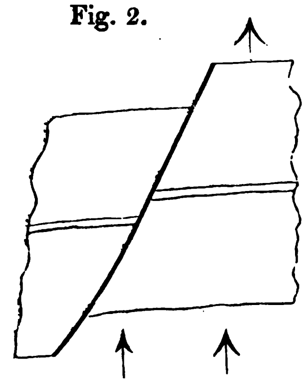


Fig. 2.

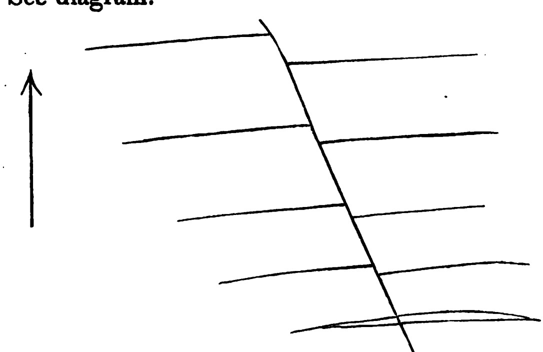


sketches. In Cornwall the majority of the *splits* are north-west, as described above, in fig. 1; consequently all the principal "*heaves*" of the country are to the right, the western masses having shifted northward more than the eastern. The red sandstone and carbonaceous series, intersected by a split near Tiverton in Devon, has been shifted northward on the western side nearly half a mile. In the vicinity of Tavistock the same kind of "heaves" are seen in the Devon Consols, &c. There is a great northward "heave" near Gwennap, produced by the great cross course traversing the North Downs; and also several in the Camborne district. See Plates XVI., XVII. The direction of the "heaves" is generally expressed by *right* and *left*, because the same expression serves on approaching them on either side. Some suppose that the nature of "heaves" depends on the direction and inclination of the mineral veins or transverse fractures; but this is a mistake: the movements of the masses are quite independent of the lodes or fissures, and would be the same had they not existed. Nor does it follow that the dislocated veins should be always "heaved" on the side of the obtuse angle, as generally supposed, because this depends on the angle of the fracture itself.

The cause of the above order in the dislocated masses is made manifest when we examine the nature of the mechanical disturbance. Admitting the magnetic force to act in the meridian, the direction of the *oblique splits* destroys the parallelism or uniformity of the polar forces; consequently the masses presenting the largest transverse base to the south will be propelled northward at a greater force than those terminating in pointed angles in that direction.

With regard to ruptures produced by tension, they are of daily occurrence; and although those who live on the surface are unconscious of such subterranean disturbances, yet the miner who spends the greatest part of his life in the subterranean laboratory of nature is well acquainted with such phænomena. On one occasion, in the Boston Vein, Peak Forest, the solid rock was rent on the south side in a vertical direction to the depth of thirty-six yards below the place where the miners stood, and sixteen yards above them, and accompanied by a report equal to that of a cannon: one part of the rent was wide enough to

admit a man's body. Sudden concussions and internal sounds are often heard by miners in all countries, thus causing much fear and superstitious ideas, well known amongst the German and South American miners. All wet grounds in rocks containing bands of hornblende, talco-magnesia, carbonate of lime, and impregnated with arsenico-sulphuretted minerals, are very active, and cause much expense and trouble in timbering. The great meridional splits are generally so full of water that the lines of springs thrown out along their direction afford considerable facilities in tracing them. Hence, by means of the porosity of rocks, and of fissures that traverse them, these meridional conductors, or irrigators, bring in water with a variety of substances in solution, and keep the rocks in a state of saturation. These conditions are highly favourable to the transmission of minerals from one place to another by electro-polar action; consequently, when the crystalline rocks are much fractured, a variety of effects must take place both mechanically and chemically. We have, therefore, in fissures and vacuities receptacles for numerous mineral productions, the character and quantity of which depending upon the *conditions* under which they may exist, to be explained in the next chapter. In a series of parallel fissures (E. and W.) intersected by a diagonal split, we generally find the "heaves" or dislocations to the north much greater than to the south. See diagram.



This may be seen in the Consolidated Mines and Camborne district, and also near Tavistock. There is scarcely any rich copper mine without being intersected by N. and S. courses, and the more numerous the more productive, and *vice versâ.* In-

deed, the circumscribed nature of the mineral parts of the fissures or lodes, together with that of the aggregated mineralized masses conforming to the angle of the cross-courses, and the structure of the bounding rocks, and the influence the impermeable meridional splits and conducting N. and S. veins have in the accumulation of the useful minerals, are well exemplified in the great mines of Cornwall and Devon, and show most distinctly how essential it is to study these natural laws to ensure the success of the explorations. The great "cross-courses" in the parishes of Gwennap and Tavistock may be traced on the surface by the range of large and productive mines, which lying more or less in a N. and S. direction, indicate their intersection and enrichment by the meridional joints. The same may be observed at Redruth and Camborne; hence the old saying of the miner, "the great cross-courses are the parents of all the ores." Before we proceed with the chapter on mineral veins, we shall trace the effects of the splits and ruptures on the superincumbent sedimentary masses, more especially in coal-fields.

CHAPTER XII.

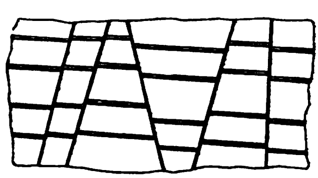
FAULTS IN COAL SEAMS.

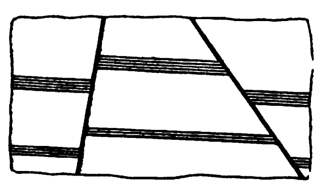
We have already alluded to the effects of cleavage, *i. e.* that all the sedimentary rocks are liable to be cleaved by the primary base; this is particularly the case with coal, which greatly facilitates the extraction of the coal-seams. This is well displayed in the coal-fields of Virginia, owing to the proximity of the beds to the gneiss and other schistose rocks below. Parallel to the stratification of the seams are first, the partings, analogous to the exfoliated subdivisions of rocks; intersecting these, in a more or less vertical position, are the polar cleavages; these last separations are sometimes called "backs" or "bright heads," from the coals separating at these cleavage planes like slates, but with clean and highly-polished surfaces, except when, as it often happens, the complanatory lustre is covered with a

rusty-looking scale, or with the well-known sparry concretion, consisting frequently of carbonate of lime, and sometimes carbonate of iron, also magnesia, according to the character of the inferior basin, these substances being derived therefrom by infiltration of the minerals held in solution. Besides these, there are fissures passing almost vertically, nearly at right angles to the planes of cleavage, being fractured divisions, and are appropriately denominated "cutters." Indeed, these geometrical divisions are similar to those observed in fine roofing-slate quarries, and consequently, by means of this compound system of natural series of lines, the coal, like the blocks of slate-rocks, is often broken, or separated from the seam in parallelopipedal masses.

The "slips" and "faults," although sometimes but mere joints, cause, nevertheless, great dislocations in the stratification, like the "flookans" in the primary base already described. A vertical dyke, running at right angles to the series, only disjoints the beds, neither effects their elevation nor longitudinal position, being similar in this respect to the same kind of cross-courses in the crystalline rocks. When the polar joints, or great main faults, are very *oblique*, a vertical dislocation will take place, and the masses will be elevated and depressed, and press and slide on each other until the equilibrium of the pressure on the soft base below is restored.

The general condition of these dislocations will be seen on reference to the following diagrams.





The greater the acuteness of the angle of the fault, the greater is the dislocation. If the angle formed is obtuse, or in other words, if the observer looks at the dislocating joints from the floor of the opposite bed, the effect will appear as an upthrow. When the angle is 90°, vertical dislocation seldom takes place. We shall now explain the cause of the order, or the law, of these

disturbances. As the carboniferous strata rest on a semi-fluid base, such as beds of clay and moist carbonate of lime, and rocks in the usual high degree of saturation, the main polar divisions, if obliquely cut, will disturb the uniformity of the pressure, consequently the isolated masses will gradually subside or elevate according to the angle in which the masses are divided by the "faults." The most simple and frequent cases of such dislocations are represented below. Let us consider what would be the consequence of the oblique subdivisions of the coal seams in fig. 1 resting on a soft and semi-aqueous base. Ac-

Fig. 1. *Angular Splits and Fractures.*

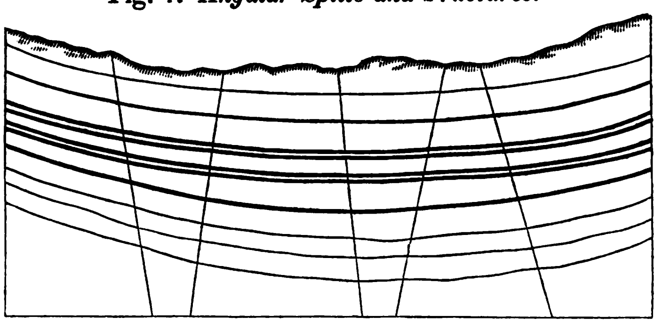
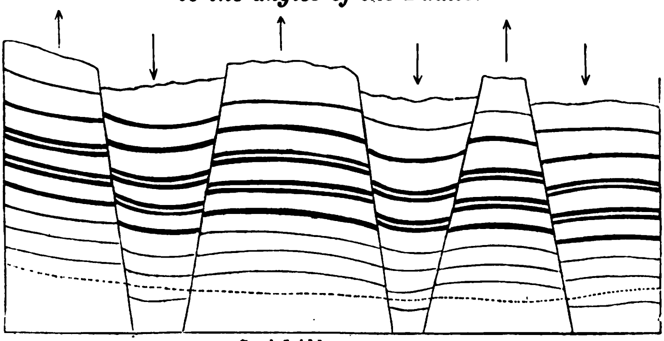


Fig. 2. *Subsidence and Elevation of the separate parts according to the angles of the Faults.*

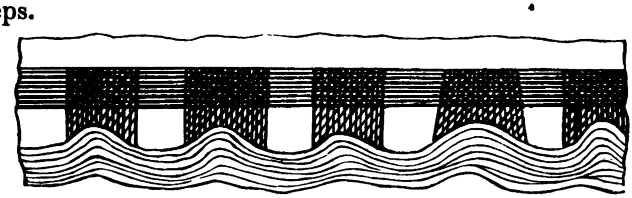


Semi-fluid base.

cording to the laws of statics, the pressure will increase as the lower area of the masses becomes less than the upper, and *vice*

versâ: the weight divided by the area will give the amount of each, therefore the *wedges* will *sink* and the *parts between them rise* to restore the uniformity of the pressure on the soft base, as illustrated in fig. 2. The planes of these joints, and also the oblique transverse fractures caused by their movements, are often seen with a polished striæ from the rubbing or sliding of the separated masses on each other; and as the direction of the action must necessarily depend on local conditions, being sometimes vertical, horizontal, or diagonal, the polished grooves are not always parallel, but often curved and in various undulations.

The above various effects are well shown in almost all workings carried on in the coal-measures. We sometimes find the roofs and pavement gradually unite, leaving not a trace of coal behind, the clay or softer shale disappearing also at the same time, as if they were squeezed out by the weight of the superincumbent strata; the pressure of which having been increased by the angular separation. This is well exemplified in what are called creeps.



When the pavement or bottom stratum under the coal happens to be soft, being commonly fire-clay and shale, and the pillars somewhat small, the pillars will sink and the floor rise as described in the figure; to avoid these effects we are obliged to form large pillars. Sometimes the sedimentary beds are separated vertically upwards of 1000 feet, yet the masses of the uplifted and depressed strata do not present such irregularities on the surface as to indicate these disturbances. These actions have been going on so extremely slow during many ages as to allow sufficient time for the superficial parts to be modified at the same rate, obliterating thereby all irregularities on the surface by atmospheric and various other causes. It was supposed that even these "faults" were the result of violent mechanical convulsions produced by volcanoes, but such notions have arisen

from the want of a more practical knowledge of the general character and order observed in the disturbed strata. "Faults" are often filled with clay and various other substances from the base below, or from the softer interstratified seams by means of the pressure above described; these substances render the "faults" impermeable, and, consequently, the water percolating in each mass is retained by these natural dams, which is of great advantage to the independent workings of coal districts. From this cause the coal on one side of a fault is often different from that on the other side; sometimes losing its bituminous quality and becoming impregnated with other elements. Occasionally a perfect transition may be observed from anthracite to bituminous coal, the modifying cause being from the former to the latter.

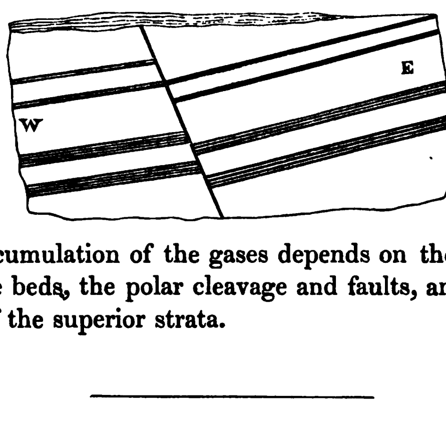
The theoretical geologists have an idea that the hornblende seams which are interstratified in the carboniferous beds of England, were forced into their present position in an incandescent state, from their imaginary igneous nucleus, and they have endeavoured to point out the centres of eruption or focus of volcanic force. Several such centres of eruption have been long pointed out in the Wolverhampton district; but, like a number of other such vague and unfounded notions, they only serve to amuse the uninitiated, and are scarcely noticed by practical men of science. The masses of green rock called "trap," at Pouk Hill, the Nechells, and other localities in the Wolverhampton district, are not owing to these points being centres of eruption, but simply to the intrusion of semiaqueous substances by cross-courses and the bed of greenstone (which had been forced in as hornblendic clay) throwing off branches from its upper surface: the under part of the above bed of trap-rock rests uniformly on the seams below, and the coal underneath it is found in a comparatively undisturbed state, thus showing that the disturbance in the district beyond the main faults is confined principally to the upper part of the series. This trap or hornblende seam, which has been gradually forced into the sedimentary divisions from the main "faults," is always moist, and frequently found as soft as clay. The degree of moistness indicates the degree of disturbances; and the beds in contact are found fractured, and saturated with mineral solutions, and the cracks filled with calcareous, siliceous or hornblendic matter, proceeding from the

trap-bed. As the upper beds present the least resistance to the forcing and swelling power of the intrusive semi-aqueous seam, the fractures and veins are formed in the upper portion, and they bear the same analogy or relation to it as the quartz veins do in the slaty rocks. These veins and branches are constantly formed by the squeezing of the separated dislocated masses, similar to what may be seen in a bed of soft clay confined and covered by a layer of stones or bricks; the clay is forced up between the joints according to the amount of pressure; and this is what is termed centres of volcanic eruptions in the coal formations. When the coal happens to be in contact with the above active moist rocks, it is more or less impregnated with mineral, especially the peroxide of iron, and therefore, when dry, becomes somewhat reddish, vulgarly called "burnt coal;" but igneous fusion has had no more to do with this change than with the "gases," or with any other slow chemical saturation by the humid way. One of the most common effects of heat upon limestone, is to deprive it of its carbonic acid and reduce it into white powder. Chalk, when intersected by veins of any substance containing carbonic acid, becomes partially converted into marble by the absorption of the acid. However, like all theories suggested by eminent men, and made fashionable, they are by a little philosophical coaxing applied to account for all phænomena. The assumed igneous theory appears by its supporters to possess extraordinary properties, remaining unaffected *in* water as well as in air, hot or *cold*, according to circumstances; capable of converting limestone into lime or lime into limestone, coal into coke or coke into coal, as they may feel disposed to apply it, and totally uncontrolled by any fixed principles or known laws of heat. Such is also the case with the glacial theory; all polished striæ is attributed to its effects, hence an icy epoch is assumed in the history of the sedimentary series. These kind of hypotheses are most arbitrarily founded on very loose observations, and not only most irregularly applied, but generally so irreconcileable to the observed phænomena as to render the science of geology as yet unacceptable to practical men.

To return to the subject of the chapter on the effects of faults, we find that not only is the water separated and retained within given areas, but also the subterranean gases, the carburetted and

sulphuretted hydrogen, the local accumulation of which is much influenced by the angular position of the "faults," dip of the beds, and the planes of cleavage.

In working near the crop of the coal, we are seldom troubled with gas, and a very indifferent system of ventilation may be sufficient for the purpose; but in the dip on the other side of a fault the gas accumulates so much as to render it no easy matter to effect a perfect ventilation and prevent the gas remaining stagnant in the upper recesses. I know a colliery on the east side of a fault, where the coal seams rise towards the surface; the colliers have been working for upwards of fifty years without the least obstruction from fire-damp, with only an ordinary means of ventilation; whereas, on the west side of the fault, the seams are highly charged with carburetted hydrogen, being, as it were, retained by the fault. On the east side ventilation is effected with the greatest facility; but on the west side of the fault, without the aid of a very judicious method for the extraction or the escape of the gas as it evolves, the consequences would be very serious. See the annexed section. In a word,



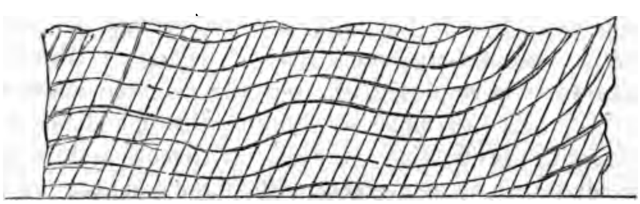
the local accumulation of the gases depends on the angular position of the beds, the polar cleavage and faults, and the impermeability of the superior strata.

CHAPTER XIII.

ROOFING-SLATE FORMATIONS.

Although slate quarries are so common, yet there is no subject more interesting and instructive in questions connected with the semi-crystallization of consolidated sedimentary rocks,

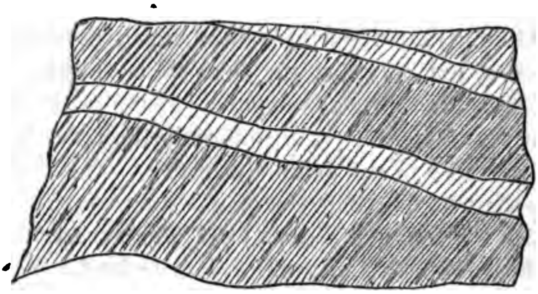
and geological dynamics, as the study of these formations; notwithstanding the facilities presented to investigate their character, the phænomena they exhibit, and the true nature of their structure, they are scarcely known to the scientific world. Many imagine that the planes of cleavage are the same as the planes of the sedimentary bedding, and that their present high angle, or vertical position, is owing to the stratification having been lifted up on edge by subterranean forces. The sections in Plates VII., VIII. and IX., which have been taken from nature, will show at onee, not only that the cleavage or splitting planes of the rocks have been formed subsequent to the consolidation, inasmuch as they intersect them uniformly through all their undulations, but also in one definite direction. The average bearing of the best roofing-slate cleavage is a few degrees to the E. of N., which is the case in Germany, in Nassau, on the banks of the Moselle, in Wales, Cornwall, and in Ireland. Whenever a slaty formation is thrown from this angular position by any intrusive crystallizing rocks, the uniformity of grain and tenacity become partially deteriorated or even destroyed, and quartz veins or hornblende gradually form by the contortion and fractures, as shown in Plate X. taken in North Wales. In the Welsh slate rocks, even after the sedimentary planes have been completely obliterated, we detect the old bedding by various shades or tints, as shown in the following cut. These effects, as already stated,



do not apply solely to mere quarries, but also to extensive chains of mountains in both continents. The best slate rocks are separated from the quarries in geometrical figures approaching that of felspathic crystals. At the base of these great slaty rocks, we find in many places, both on the continent and also in North Wales south of Snowdon, the gneiss, primary schist, hornblende and granular granitic bands, in their usual structural bearing,

corresponding to that illustrated in Plate VII., section of the Andes, and thus showing not only their contiguity, but the cause of the cleavage of the superincumbent sedimentary bedding; the angle and bearing being always conformable.

We frequently observe a similar effect having been produced in veins of porphyries, and, subsequent to their consolidation, in slaty rocks, as shown in the annexed diagram.



When the cleavage planes and the old sedimentary seams conform, they produce strong slates and present fine phases of crystalline flakes; when at right angles to each other, the slates are somewhat brittle and do not break into long splinters, but possess a fibrous texture.

In a previous chapter we dwelt on the phænomena of order observable in the polar cleavage, and also alluded to the fact that the subterranean current passing through the cleavage planes causes a westerly deflection of the external current, as indicated by the position of the magnetic needle. When a weak solution like sea-water is employed, the westerly variation amounts to about 10°; hence the polar structure or cleavage planes do not coincide with the direction of the magnetic needle, and are found, as already stated, on an average, on the large scale bearing a few degrees E. of magnetic north, but in various undulations. If, in our experiments, we wish to retain the natural position of the magnetic needle, whilst within the influence of an active but weak battery employed to produce cleavage in a mass of clay, it will be necessary to place the apparatus in such a position as will make the internal current of the battery from pole to pole to run from S.W. to N.E., that is, in fact, parallel to the terrestrial cleavage.

On this arc of variation between the internal and external magnetic currents, depends the principle of the electro-telegraph. By means of experiments we can also produce the elongated N. and S. veins and the E. and W. fractures. We also observe a general tendency of the liquid and the soft mass of clay to press on the oxidating pole of the battery. If we divide the mass of clay obliquely from one side of the copper to the opposite side of the zinc plate, by means of a fine impermeable substance, so as to represent a diagonal split, a dislocation is produced in the transverse lines, and the cleavage slightly twisted; the triangular mass with the greatest base on the diverging or negative pole, being forced and compressed against the zinc plate to a greater degree than the opposite mass.

In order to show this linear polar effect more distinctly and quickly, and how fluids propagate polarity in the molecular compounds, let a few filaments of tinfoil be placed on the surface of water in an oblong trough, and dip into each end wires from the two extremities of an active battery, the metallic ingredients will immediately acquire polarity and arrange themselves in a linear direction corresponding to that of cleavage planes and the fibrous structure of the rocks from pole to pole. Various solutions of metallic substances allowed to crystallize very slowly between the poles, exhibit the same phænomena, and identical to that observed in the great subterranean terrestrial battery, as already explained*.

* We have already insisted that cleavage planes are formed *in the direction of the currents from pole to pole.* Experiments have been made with the view of imitating these crystalline planes, by placing a mass of clay between the poles of a battery, and it has been supposed that the small transverse *fissures* produced by the tension represent the phænomenon of cleavage. A very slight examination will show the distiuction between them. Those who may feel disposed to imitate real polar laminæ must furnish each pole with a piece of laminated rock; without this preparation cleavage planes cannot be produced by artificial means. A mass of clay jammed between the walls in a vein of fracture will be cleaved across by the natural magnetic currents in a very few years. It is this constant cleaving action which is the cause of veins becoming obliterated, as represented in Plate IX.

CHAPTER XIV.

MINERAL VEINS, THEIR FORMATION, AND THE GENERAL CHARACTER OF THEIR CONTENTS.

Besides the conflicting opinions respecting the origin of mineral veins, much confusion has also arisen from the very loose signification applied by miners to the terms *veins* or *lodes*. Such terms are often given to almost any kind of mineral deposit which affords a foundation for mining operations, however widely it may differ in character from the definition of these terms in the ordinary sense in which they are taken. In fact, the mere detection of a crystal of mineral in a rock, and more especially flakes and small flat nodules of minerals enclosed in the cleavage of the slaty rocks, is sufficient to cause some persons to conclude that there *must* be a lode in the vicinity to produce such minerals. They suppose minerals can only come from veins or lodes: and again, when small masses of ore are discovered in slates, however insignificant they may be, it is considered that there must be not only lodes, but unequivocal indications of richness in depth.

These notions are encouraged by mining jobbers, and are the means of a deceitful system of mining being carried on at the expense of the unwary capitalists, destructive alike to the interest of the tenant and landlord, as well as to the injury of legitimate mining.

It has been already stated that the rock is the parent of the mineral, *i. e.* that it is the soil as it were out of which the minerals grow, with the exception of what may be brought in addition by aqueous conductors; and from the appearance of the rock, in composition and texture, or internal structure, we can determine its probable production. The manner in which the metallic or mineral products become developed depends on mechanical causes, and the internal compactness and aggregation of the crystalline compound.

We have already shown how metals are produced and liberated from rocks by decomposition, and shall now explain the formation of sulphuretted ores in the fissures of rocks from mere joints to the magnitude of great lodes.

Sulphurets were formerly considered as scarcely explicable in the wet way, sulphur being supposed insoluble in water; but we find innumerable springs holding sulphur in solution, such as sulphuretted hydrogen, as already explained. All metals are held in solution in a weak alkaline mixture and in different compounds. Carbonate of lead is soluble in alkali and lime, and precipitable therefrom by sulphuretted hydrogen. It has a greater affinity for lime than for any other earths; hence limestone formations contain lead in preference to other metals; marshes are also usually more productive of masses of lead ore than the higher and drier parts of the rock. The carbonate of lime not only accompanies galena or sulphuret of lead in the limestone rocks, but also very frequently in the clay-slate and porphyritic formations, as a matrix of the ore.

The most pure metals, when sufficiently divided, are soluble in water; and it has been shown that silver, as well as mercury, lead and copper, &c., are taken up by water and deposited on the surface of rifts, as in the Christiania mines in Norway, in Peru, and in a number of other mining districts. When, therefore, water impregnated with sulphur meets with the same element charged with metals, permeating the joints and pores of the rocks, precipitation takes place and forms a compound in accordance with the laws of affinity; but this formation of sulphurets is again subject to be dissolved and dispersed by an alkaline reaction, as proved in many instances.

In Peru and Chili pieces of wood that for years had been left standing in old mines have been found partially converted into siliceous fossils, and others again covered only with calcareous spar, metallic silver, grey and red silver ores, and fine crystals of iron pyrites, by solutions from metalliferous rocks. New crystals of pyrites, both iron and copper, have been found in the old decomposed heaps of pyritous refuse in South America, formed during decomposition.

Arsenico-sulphuretted waters have been detected, not only in foreign countries, but also in Cornwall and Devon. Antimony has been found in a state of solution in the mine of Santa Cruz de Mudela in Spain, and in many mines of the Americas. The sides or walls of the old mine at Mausterappel have been found covered over with natural cinnabar that had transuded from the

rock subsequently to the stopping of the mine. I have seen similar formations in old workings in New Granada, and in an excavation at such an altitude in the rock as would not admit of its being filled with water; yet a thick crop, or an efflorescence of black ferruginous crystals, had been formed on the walls (analogous to the formation of nitrates on the wall of an old cellar), containing a large proportion of fine grains of gold. At Wolfclough mine, in the county of Durham, which was closed for more than twenty years, and opened again, needles of white lead ore were observed projecting from the sides of the veins, more than two inches in length, being in fact equal to a vein two inches thick, formed during twenty years.

To avoid confusion, and to render the principles which are here maintained respecting the origin of mineral veins intelligible and practically useful, we shall distinguish the variety of veins or lodes, and illustrate their respective characters by diagrams. Plate XIV.

Fig. 1 is a section of an ordinary lode, being a fissure or a fracture, obliquely, or at right angles to the pores, grain, or cleavage of the rock, in which minerals are found in masses according to the metalliferous nature of the "country," and running more or less E. and W.

Fig. 2 exhibits a split vein, or a lode enclosed in the grain or cleavage of the rock, and running more or less N. and S. This variety is more favourable for lead and silver ores than the former, and is unfavourable for copper.

Fig. 3 are cross courses. These are aqueous conductors, or great irrigators of the metalliferous rocks, without which the lodes are seldom productive of large masses of ores, and more especially copper. The greater the amount of disturbances the more favourable for the accumulation of minerals, and *vice versâ.*

Fig. 4 are oblique joints between a split and a fracture ("caunter"), favouring in many instances the accumulation of minerals; and when N.W. productive lodes.

Fig. 5. Seams, or ore forced into the joints of the beds of the rocks, sometimes called "floors,"—a very unfavourable position for the accumulation of minerals, and more especially when the beds dip to the south.

After the tension has produced the slightest fracture, and caused a break in the continuity of the internal pores, a stoppage of the aqueous current takes place and a crystallizing action commences. Sulphuretted ores are always subject to crystallize; these, with the crystallization of quartz and other substances, exert a force indefinitely strong, and will force a whole mountain forward. Even water on the point of crystallizing into ice, bursts metallic vessels and displaces immense masses of rocks from *situ* in the snowy region. In the formation of veins in the primary siliceous rocks quartz takes the lead, and commences the opening and filling of the vein.

The veins found in the calcareous rocks are generally first filled with matrix found in the series, such as carbonate of lime and baryta, and the minerals subsequently brought in, and accumulate in strings or separate bands in the middle of the lode, or dispersed throughout the gangue.

The sulphuretted metals thus formed in veins, accumulate or gradually augment in different ways; they may be conveyed in their sulphuretted state through the pores of the rocks to the fractures, and therein crystallize (being the ordinary mode in
hey are formed), and also by the metallic solutions tra-
the pores meeting with sulphuretted hydrogen in the
s, supplied from the cross-courses, and thus become
ized. The cross-courses not only supply elements to
chemical activity, but divide also the district into bands,
ng the mineral within certain limits, thus enriching one
the expense of another portion of the rocks.

CHAPTER XV.

FILLING OF JOINTS, FRACTURES, CAVITIES, ETC. BY THE SUBSTANCES PERMEATING THE ROCKS.

ooking at the sulphuretted minerals which have replaced
nic remains in compact argillaceous and calcareous sedimentary rocks, the reader may be prepared to expect not only a

similar action, but one of greater amount in the fundamental crystalline series. When we find mollusc and spirifera shells formed of sulphuret of copper, iron and lead, in their exact form, we cannot avoid coming to the conclusion that these mineral substances must have been introduced in solution into the cavities left by the decomposition and disappearance of the shells. These effects are so common, not only in the Americas and on the Continent, but in many parts of England, in the chalk, lias and mountain limestone, as not to require reference to any particular locality. We find also sulphüret of iron and of lead in the minute fractures of fossil wood and bones in the sedimentary calcareous rocks. Even the carbonate of lime of many fossil shells does not always appear to be that of the original, but to have been infiltrated into cavities left upon the disappearance of the matter of the actual shell.

Again, in the crystals of felspar, decomposed in the body of a rock in a homogeneous kind of porphyry (Elvan), the original substance of the crystals are frequently removed, and are replaced by peroxide of tin or pyrites, showing most distinctly that mineral matter in solution permeates the pores of the hardest rocks in the absence of veins or joints. In a word, looking broadly into the general character of our rocks composing the external part of our globe, both primary and secondary, we find them a compound of all the known elements in a semi-aqueous state, and, as a necessary consequence, have always a tendency to fill all cavities, joints and fractures, with mineral matter in solution, which crystallizes by degrees therein, in accordance to the laws that govern the different compounds.

According to the preceding observations, we would naturally conclude that all fissures, be they joints or fractures, would partake more or less of the mineral character of the rocks so divided or broken; that the substances principally filling the joints and fractures in limestones would be calcareous, while those amid siliceous rocks would be quartzose, and in hornblendic rocks, veins of greenstone or basalt, as is usually the fact. However, occasional variations do take place; for instance, in a compound of carbonate and silicate of lime, we sometimes observe quartz veins, and on the contrary we find veins of carbonate of lime enclosed in siliceous formations. Indeed nearly all the primary

limestone is so situated, and is usually found in great bands enclosed in granite and gneiss.

The filling of cavities and small fissures in crystalline and other rocks by carbonate of lime is very common, even when calcareous rocks do not constitute any large proportion of the bordering mass. The ready solubility of the carbonate of lime, when saturated with an excess of carbonic acid, occasions the passage of the former substance from calcareous rocks into the vesicles of others; and if not again decomposed and removed, it would prevent the deposit of other substances passing in solution through them. Sometimes the decomposition of the felspar in porphyry will liberate a large proportion of lime, which may issue out and be deposited on the surface of another rock, or be precipitated within its cavities, without the parent rock indicating to an ordinary observer any calcareous properties. This is commonly seen in the western chain of the Andes*.

When we reflect on the composition of the water which may insinuate itself into a fresh fracture, intersecting series of crystalline rocks of variable composition, all in a moist state, saturated and composed of elements susceptible of generating active chemical actions, when partially mixed in solution or coming in contact, the question becomes much more complicated than the mere permeation or infiltration of a simple substance, and easily accounts for the great variety of minerals we sometimes find crystallized together in our mines.

Let us take as an example the following variety of rocks which mineral veins commonly intersect, viz. the granitic, hornblendic, schorlaceous, felspathic, and consider what must take place in the fractures, when the formation is traversed by north and south cross-courses, effecting a linear aqueous communication with the internal moist rocks and sea-water. Before we can fairly appreciate the chemical action during the decomposition that will ensue, it is necessary to reflect well on their respective composition.

Common granite is composed of silica, alumina, potash, and often soda and lime, magnesia, oxide of iron, oxide of manga-

* Substances crystallizing from solutions are more readily formed in rocks of the same character than in others.

nese, fluoric, carbonic and other acids, and traces of minerals partially disseminated.

Hornblendic,—silica, alumina, lime and magnesia, protoxide of iron and manganese, and acids in a different proportion to the granite.

Schorl rock,—silica, alumina, potash, soda, lime, magnesia, iron, manganese, boracic and other acids, with a partial dissemination of the peroxide of tin.

The *felspathic argillaceous* (killas or granitic clay-slate),—a homogeneous compound of the elements of the granite partially decomposed, with a large proportion of alkali, and an excess of mineral solutions.

The above rocks, in consequence of their moist state, form a transition into each other at their junction, sometimes in meridional bands, and also when lapping on the granite. The great *cross-courses*, or meridional splits, irrigate the whole series with saline solutions from the sea, and thus render the mineral compound in a state of chemical activity.

The *sea-water* is composed of chloride of sodium, sulphate of soda, muriate of lime and magnesia, sulphuric, phosphoric and many other acids, and frequently traces of metallic solutions.

We have to regard not only the combination and mixture of such elements when introduced into the fractures, but also the effects of the constant tension of the electro-magnetic power permeating the whole mass, causing mechanical disturbances and reactions, and double and treble decompositions amongst the various compounds. A certain degree of heat must be produced when the sulphuric acid comes in contact with infiltrated fresh water, or when the acids attack the bases; the water will be decomposed and sulphuretted hydrogen will be formed, and this will act as a strong metallic solvent, and in absorbing the latter sulphurets will be formed; the hydrogen in evolving towards the surface would decompose the upper part and reduce the minerals into oxides (gossans), thus rendering the mineral veins visible on the surface. A reaction may again take place which may reduce the minerals from sulphurets into carbonates, muriates, oxides and metals. Should sulphurets of copper, silver, iron, &c. become in contact with a solution of common salt and a weak solution of sulphuric acid, the water will be decomposed, and the

iron and the salt will be attacked by the acid and be reduced into sulphates of soda and iron. The sulphate of iron will dissolve the silver, and the chlorine will then convert the silver and copper into chlorides, and both of which may be deposited in joints or vacuities in that state, and remain so until attacked again by agents which may change them into carbonates, oxides or metals.

The sulphuret of copper, when formed in the neighbourhood of carbonate of lime, is subject to be decomposed into a green carbonate, the lime is precipitated and partially changed into a sulphate. Thus the "greens" of the miner are commonly formed, and may be seen on old white-washed walls, or infiltrating through rocks containing carbonic acid, or decomposed vegetable matter. All chemical actions evolving gases tend to ascend; thus crystals radiate or form at right angles to the surface, and grow out, as it were, like vegetation, the metals efflorescing in an arborescent form. There is always an upward action in the mineral as in the vegetable kingdom; in short, all substances that liberate gas exhibit this effect. Hence the grand region of natural chemical operations and the production of minerals are brought within our reach, supplying the wants of all generations, by slow and apparently feeble actions, which do not produce any material injurious effects on the vegetable kingdom, nor yet on the habitation of man, beyond those few local disturbances occasioned by a too powerful action of the elements.

The cross-courses, generally speaking, supply the active mineralizing agents, such as the sulphuric, carbonic and other acids; the rocks provide the minerals and the alkalies. The compounds are formed only at the points, where the metallic sap oozes out. Thus a rock which may be very favourable for the formation of ore, may not indicate the presence of the mineral by impregnation or in a state of aqueous dissemination. Again, it often happens that a compound is formed by the aid of several elements brought together from different points, similar to the gradual formation of the trunk of a tree; the distinct elements of which are brought from the soil by the conducting power of the roots. The seed, with its active principle being the fixed point, causes the first action on the elements surrounding its immediate neighbourhood;—the plant increases in bulk, and be-

comes more powerful until the required elements are abstracted from the soil*. This deficiency becomes by rain or aqueous saturation replenished, and the tree increases in magnitude by the constant supply: and such are the local effects of mineral crystallization.

The formation of a crystal will cause a local attraction towards it of similar elements; and however slow this process of metalliferous aggregation may appear at first, yet the decomposition and the crystallization of the separate elements become by degrees very powerful, from their respective cohesive forces, and these forces increase in energy proportionably to the increased bulk. The different elements after separation will cause new combinations and arrangements till they arrive at a comparative quiescent state, the whole of the contents of the bounding rock being abstracted prevents further metalliferous accumulation. This is the case with many of our great mines; the rocks in which the rich veins are enclosed are like exhausted soils, having all the nutritious elements drawn out. Again, the reason why cross-courses are so important for the enrichment of a district, and yet poor in themselves, is evident, inasmuch as they are only the irrigating channels, bringing in active chemical agents to combine with the elements of the rocks to form the minerals; and as they are constantly in a state of activity, filled with strong solvents, no important mineral crystallization can take place in them under such conditions.

The greater the degree of metallic saturation, especially iron and arsenic, exposed to the permeation of acids and salts, the greater is the degree of mechanical and chemical disturbances, and the heat produced; and also the local accumulation of minerals. These frequently give rise to mineral and thermal springs, and some substances would be deposited, whilst others would be carried away in solution. A mineral may lose its argentiferous contents by an excess of sulphate of iron dissolving the silver, and this metal may be precipitated in another joint on a barren rock, or any other substance, and thus form a vein

* An illustration of the great mechanical power produced by a seed growing into a tree in the crevice of a strong wall, may be obtained in the ruins of old abbeys. The strongest walls, and even rocks, have been disturbed and broken by the growth of trees.

of silver in the neighbourhood of a copper lode*. The power of the ordinary spring-water to dissolve the hardest rocks is much greater than is generally supposed. Small streams in the course of time perforate and groove basaltic rocks, as is frequently observed in the ravines of South America.

All substances become dissolved in the course of time in the ordinary temperature of the subterranean liquids. Sulphate of baryta, a substance very common in lead mines, has been termed insoluble, although found in such a state as to leave no doubt of its being deposited from solutions.

In some districts on the continent (Prussia) we find the indications such as to warrant the supposition that the baryta came from one direction whilst the lead came from another; the combination of the two producing the desired effect.

Water with carbonic acid and potash in solution coming in contact with sulphate of baryta, will effect a partial decomposition at a moderate temperature; and should another element, such as lime, abstract the acid, sulphate of baryta will be reproduced. The changes taking place, and the evolution of sulphuretted hydrogen, and the consequent variable degrees of intensity, must cause various products and change the sulphurets into carbonates, oxides, &c., from below towards the surface, as already explained.

After the fissures have been produced and the crystalline aggregation of minerals having forced open the joints to the magnitude of lodes, another variety of solutions may percolate through the pores, or cross-heads, and contaminate the contents of the veins already formed with quartz or other substances, or dissolve the minerals and carry the same away to other vacuities, or the pores or cleavages of another rock. Sometimes the solutions permeating the series are so free of silica that the spaces between the mineral masses in the veins are left hollow; presenting beautiful cavities,—decorated by brilliant crystals, and radiating from the surface on which they are formed. Gold, silver and metallic copper are frequently formed in such cavities, growing out in elegant moss-like, or arborescent forms, the whole

* Herland, Dolcoath, Crenis and other copper mines have produced silver under such circumstances.

exhibiting a rich display of the flowers, as it were, of the mineral kingdom.

Thus we are able to comprehend the varied conditions of mineral veins, and the development of minerals in certain rocks by chemical affinities, governed by the terrestrial electro-magnetic forces.

With reference to the effect of a slow electro-magnetic action on matter in a liquid state, it has been so much pointed out, that it is scarcely necessary to repeat it. However, as the object is to lay before the reader as many facts as possible under different aspects or conditions, repetition may be convenient so as to refresh the memory in the progress of our inquiry.

Various compounds are produced by a battery (be it galvanic or a simple magnet) which are not formed by the ordinary kind of experimental investigations. Disunited elements in the electro-magnetic action of nature are presented to each other in a nascent state, which is highly favourable to the formation of new combinations. For a long time it could not be conceived that such apparently feeble electro-magnetic forces as those we find in the laboratory of nature, could overcome strong affinities and decompose hard bodies, and produce new combinations. It was commonly supposed that a very energetic action was necessary to produce some of our mineral productions. In experimenting with batteries, M. Becquerel found substances considered insoluble, easily dissolved, and capable of being recrystallized; the electrical action being slow, the chemical action was slow also, so that the component molecules had time to arrange themselves according to the laws governing crystallization, which cannot be effected by chemical forces of greater intensity. All the chemical actions which have produced artificial minerals, similar to those found in veins, can only be produced by *feeble currents continued for a long period*; if we operate with apparatus of strong intensity, all the elements are isolated, and no combination is possible. To obtain an insoluble crystallized substance by electro-chemical reactions, it is sufficient to make it combine with another which is soluble, and afterwards operate by means of very slow decomposition.

Mr. Fox, in his researches, found by an examination of water

taken from different mines in Cornwall, and from various parts of the same mine, that different varieties of saline solutions now exist in neighbouring strata. "The contact of large surfaces of rock," adds Mr. Fox, "with water, differing in its saline contents from them, must generate electrical excitement; and it should not be forgotten that the circulation of water would be liable to frequent changes, in consequence of obstruction in the fissure or their occasional enlargement, so that the contents, as well as the temperature of the water, would be subject to many modifications." Hence we have abundant facts to show, not alone in foreign countries, but in our own island, the existence of subterranean electro-chemical forces in rocks, which give rise to numerous compounds and reactions amongst the elementary substances.

We may therefore easily conceive that the produce of veins of fractures running transversely to the grain are more or less dependent on the composition of the rocks in which they are enclosed. But if the veins be splits more or less parallel to the meridional cross-courses, and consequently in the direction of the primary grain and cleavage, their mineral contents will be dependent on the S.W. and S.E. oblique joints, acting as feeders like roots, principally the former, and therefore these veins are not subject to vary, like east and west, according to the character of the bounding walls. Hence a lode may carry lead beyond the productive rocks in the direction of the lode north into barren ground, and sometimes ooze out into the sandstone beds which sometimes cover such rocks. Miners, not knowing these laws of mineral productions, have never studied these important distinctions; they reason on all lodes alike, be they N. and S. or E. and W.; and their notions of strata are exceedingly vague: therefore we need not wonder at the losses incurred in mining speculations.

However, notwithstanding the want of general principles, the intelligent miners know from experience that the quality of the lodes is dependent on the character of the rocks in which they are enclosed, and also that cross-courses are essential for the enrichment of a mineral district. It matters not how favourable the composition of the rocks may be, if not cut up by meridional splits (cross-courses) so as to be irrigated from the sea with saline

solutions, and cause strong tension to produce fractures and chemical activity, they cannot be rendered productive of large masses of ore. Again, lodes situated on the E. or W. flanks of granite, are more subject to change in their direction, as regards contents, than those running parallel to the north flank. The former may pass from clay-slate to schorl rock, and thence to granite, causing a variation from a rich copper lode to that of tin; whilst the latter may continue more or less the same throughout, or at all events not subject to a permanent change. An east and west lode running direct into the middle of a great mass of granite will not only become a tin lode in schorlaceous granite, but will dwindle into minute fissures as it approaches the harder nucleus; whereas a lode running parallel to the flank, may continue for miles within the external productive exfoliated portion of the granite, between the harder nucleus and the lapping junction of the clay-slate. These various conditions change the character of the lodes often from copper to tin; again, from tin to iron, zinc, lead, &c. Examples of these changes may be seen in the mineral districts of St. Austell and Fowey, and also near Chasewater in Cornwall. (See the Plates, illustrating the principal mineral districts of Cornwall and Devon.) Indeed they are so common and so well known amongst miners in all the mineral districts of the world as not to require further comment. In South America the changes are often observed in the quality of the great lodes of fractures—from auriferous to argentiferous, thence cupriferous, zinciferous and ferruginous.

The Wenzal vein at Furstenburg runs nearly vertically from N. to S., obliquely to the more or less parallel bands of gneiss, which are about 60 feet thick, dipping east. See Plate XV.

Each of these bands form a distinct variety of rock. The first is very micaceous; the second passes into argillaceous slate; the third is hornblendic,—and scarcely any mica can be detected in the fourth. This vein is shifted in depth to the westward by several oblique flookans, or clay joints or splits, and it was between two of these impermeable veins, distant from each other about 240 feet, that it contained those riches for which it has become so celebrated.

In the first band of gneiss, the vein merely formed an imperceptible string of clay; in the second it suddenly acquired

a thickness of from 12 to 18 inches, and was composed of sulphate of baryta, antimonial silver, red silver, and argentiferous grey copper. The antimonial silver was always found in large masses. In the third band the thickness of the vein is preserved by the sulphate of baryta, but the silver ores disappear, and a little sulphuret of lead is the only ore found. In the fourth band of rock the silver ores become as abundant as in the second, but they gradually disappear in depth, and are replaced by selenite (sulphate of lime), a little sulphuret of lead, and the vein dwindles into a mere thin fissure in the bottom.

These changes, with similar local accumulation, were also found in the celebrated silver mines of Guadacanal in Spain. The angular position of the oblique flookans and the lode were the same as the one above; but the geological formation of the latter district is composed of a variety of chloritic and micaceous rocks.

The silver mines of Norway, Germany, Spain, Chili, Peru, New Granada, &c., are all, more or less, in the meridional bands, enclosed in the gneiss and the micaceous and chloritic schists; and these laminated rocks frequently contain flakes of native silver enclosed in the cleavage: and consequently the rock, apart from any lode, often contains upwards of 2½ oz. of silver per ton. Indeed I have seen rocks in equatorial America, not only enclosing silver, gold, &c. in the cleavage, but also producing silver, and even quicksilver, in rocks of a granular character, without indicating the least visible traces of such metals by careful inspection.

CHAPTER XVI.

CONTINUATION OF THE CHARACTER OF METALLIFEROUS ROCKS AND THE PRODUCTION OF VARIETY OF MINERALS IN THE FRACTURES.

The ores generally mixed with each other are those that have the same mineralizer, and the same degree of solubility, and others which are soluble in different degrees, but in point of local situation are nearest each other. Sulphuretted copper ores, yel-

low and grey, are often mixed with iron and arsenical pyrites and blende. These ores chiefly accumulate in granular rocks in east and west fractures, but are also found in isolated masses in slaty and decomposed argillaceous rocks, as already explained in the previous chapters. The black copper ore, and the green carbonate (malachite), are frequently found in granite with the oxide of tin. Sulphuretted silver ores vary from bright red to dark grey, and are generally accompanied by sulphurets of lead and zinc, and also iron pyrites. Antimony and cobalt ores are also often associated with silver and lead ores, and predominate in north and south lodes; and especially in gneiss and micaceous schists. Iron pyrites is almost an universal companion of minerals, and often causes by its chemical activity the accumulation of other minerals; hence it is a favourable indication in mining districts.

Sulphuret of lead is frequently accompanied by blende, pyrites and white or sparry iron ore, and also argentiferous pyrites, calamine and cobalt, when formed in the primary clay-slate. The sulphuret of lead formed in the sedimentary limestone contains but a small proportion of silver,—the matrix of such lodes being principally carbonate of lime, fluor and heavy spar.

Sulphuretted ores can only be formed *within* the rock; if exposed to pure water or to the atmosphere, the metals would be oxidated or precipitated: hence *sulphurets* are seldom found formed in old workings. As the quantity of sulphuretted metals that can be conveyed in a state of solution is very small, it must necessarily take a long time to crystallize and fill a vein,—and more especially in large crystals.

The substance most abounding in lodes within the primary and the older sedimentary series is quartz, in a more or less crystalline state; the colour and texture of which depend on the metalliferous quality of the bounding rock. Quartz veins of a blue and dark aspect, with cavities lined with small crystals of the same substance, is a sign of poverty in minerals; whereas the red and other friable varieties indicate the presence of iron, and consequently other minerals, if in the neighbourhood of metalliferous rocks.

Fragments of the bounding rock are commonly found enclosed in the quartzose matrix, cemented together with the siliceous

solutions. These fragments show most distinctly that they were separated from time to time from the walls of the lodes during the gradual opening, as shown in Plate XIII.

This effect alone shows the inconsistency of supposing that the lodes were at any period *open fractures* and subsequently filled by mineral matter; such conditions could never have existed. The isolated cavities which are occasionally found in the compact argillaceous rocks and limestone formation, have been open spaces, and subsequently filled by sulphurets, which have permeated through the rocks; but the fractures have been gradually opened as the crystalline matter increases, like water freezing in a joint, and capable of forcing it open whatever may be the amount of resistance.

In the mining districts of Cornwall and Devon, where the rocks are much intersected by cross-courses, the fissures, or east and west lodes, contain masses of rocks and mineral characteristic of the rocks they traverse. When they intersect the pale blue or light grey granular and massive clay-slate, or the grey and moist porphyritic granite, they contain copper; in passing into dark schorlaceous rock, the copper disappears and the lode is changed into tin. Should these rocks dip either to the east or to the west, the average of the masses of ores formed within such fracture will incline accordingly, as well as the irrigating cross-courses. Meridional joints filled with clay, or any impermeable substance, may have a contrary dip, and thus dam the mineral solutions and confine the accumulation to a more limited space than the dip of the bands of rock, and consequently cut off apparently the continuation of the dip of such bunches in the direction of the productive ground.

When a band of rock is found very dry and of a close crystalline grain, it is unfavourable to produce mineral. A mere change in the colour of the rock indicates a change in the contents of the veins. When we examine the changes in the contents of the fractures intersecting the sedimentary series, the influence of the bounding beds is much more striking than in the primary rocks; the subdivision of the beds being so distinct as to afford an excellent and most unequivocal section for studying the phænomena.

The sedimentary rocks of Aldstone Moor, Teesdale, Swale-

dale, &c., consist of beds of shales, grits and limestones, intersected by fractures; the minerals in which are chiefly found opposite the limestone beds, being the principal metalliferous rocks. See Plate XII.

The matrix of the veins also frequently change as they pass from the gritstone to the limestone; in the former it is often sulphate of barytes and spar, whilst in the latter it predominates in carbonate of lime and carbonate of barytes.

Again, the continuity of the sedimentary seams are destroyed by a dislocation, so as to bring a stratum of limestone opposite a stratum of sandstone; the veins are never so productive in lead ore as when both sides are limestones. The contiguity of the metalliferous beds on both sides of the fractures appears essential to keep up the crystallizing action from the ruptured face of the limestone.

When the strata are but slightly shifted, it is interesting to observe the tendency of the elements of each stratum to reunite obliquely with those of the opposite.

Again, we find horizontal dislocation destroying the continuity of the fissures in depth, and also divided by thin seams of clay and thick seams of hornblendic rocks, which have been forced between the beds subsequent to their deposition; and these frequently separate the contents of the veins of the respective rocks: and thus even a section of the contents of the fractures exhibits the order of the sedimentary demarcations of the bounding rocks, as described in Plate XII.

This simple fact alone is sufficient to invalidate the idea that the veins of fractures have been filled either from above or below, and clearly demonstrate that such veins have been gradually forced open by lateral crystallization from the bounding walls.

In Derbyshire the metalliferous limestone is interstratified by seams of hornblende, called toadstone. The latter rock is considered by the Plutonists, to be lava injected in a molten state into the joints of the beds. These seams are composed of hornblende, felspar and oxide of iron, and, although generally hard, are frequently found in many parts as soft as clay; and this substance is gradually and imperceptibly permeating and swelling between the seams of limestone, like siliceous veins in a moist

state, but much more active than the latter, and consequently tend to disturb and dislocate the uniformity of the series. When a vein of lead is worked through the first limestone down to the hornblende seam (toadstone), the ore is, as it were, cut off; but on sinking through this seam to another bed of limestone the lead-ore is found again, until it is cut off by a lower bed of toadstone, under which it appears again in the third limestone.

Generally speaking, the upper part of the mountain limestone series is the most productive in the north of England, and within that portion there are certain beds much more productive in lead ores than others. The ore is not only found in the fissures of the above limestone, but also in immense isolated masses in the middle of certain beds. Large quantities of lead ore and calamine are found in such positions on the Continent, as well as in England, and the hæmatite iron ore of Ulverstone is similarly formed. The metalliferous solvents necessarily accumulate in joints, fractures, horizontal or vertical, and in all cavities, especially in the producing rock; we may therefore well conceive the various characters of such mineral aggregation.

Sometimes the lead ore will ooze out of the limestone into the millstone grit, and there crystallize in masses in the direction of certain joints of the structure below; as at Mold in Flintshire. Similar masses, called tumblers, are also formed in the same manner on the back of metalliferous clay-slates in Wales and Devon. Indeed the metalliferous productions of rocks are so various, and governed so much by local physical conditions, as to render it too laborious to enter into details.

Having already dwelt so much on the character of rocks in the preceding chapters, we shall confine ourselves here to the favourable and unfavourable conditions of the angular position of the cleavage planes, fractures and meridional joints, in order to show, that however favourable the contents of the rocks may be, the granites, porphyries, clay-slates, or any other, yet, if they be not intersected by suitable irrigating cross-courses, or some other conducting medium of saturation, and fractured at certain angles to favour the formation of their containing minerals, their mineral qualities are of no avail and will deceive the uninitiated.

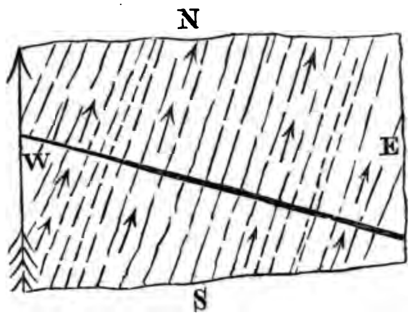
CHAPTER XVII.

ON THE INFLUENCE THE ANGULAR POSITION OF THE FISSURES, THE BEARING OF THE GRAIN AND PORES OF THE ROCKS, AND THE OBLIQUE CROSS-COURSES, HAVE ON THE ACCUMULATION OF MINERALS.

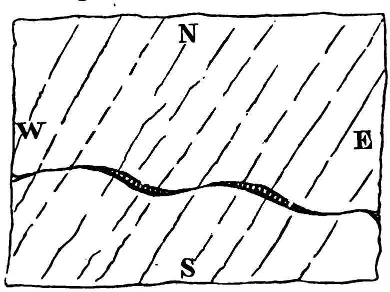
Chap 17

THE circumscribed nature of the mineral portions of a district, and even in the lodes themselves, together with that of the masses of minerals conforming to the dip of the structure of the bounding rocks, are facts well known to old miners. Not only are the bunches of ore frequently confined to the oblique intersection of an elvan by the lode, but we find also the lodes vary in productiveness according to the angle of the bends. These important observed facts, together with the well-known influence of cross-courses, flookans, slides, &c. on the local accumulation of minerals, may be seen in all mining districts; thus showing how essential it is to study the laws by which they are governed to ensure success in mining operations. We are prepared to find from the evidences brought forward in the preceding chapters on the polarity of crystalline aggregations, the order of the structure, the tensions, ruptures, and constant aqueous chemical activity, that these mineral productions are not the effects of blind chance forced up in all kind of rocks, or of violent igneous catastrophes by internal incandescent matter, but according to laws and order as beautiful as that observed in chemical operations, and in the economy of the vegetable kingdom. However, any attempt at generalization or prediction founded on local effects, without the necessary acquirements obtained from long and extensive practice, underground as well as on the surface, in all the various complicated cases, would lead to incorrect analogies and conclusions from wrong assumptions. For the want of sufficient experience in different mining districts, many persons have taken the exceptions for the rules, and thus led to error. It has been shown that the cleavage planes of the schistose rocks, the pores of the compact clay-slate, and the porosity of the granite have a general bearing a few degrees east of true north, and we find that the fractures approaching a

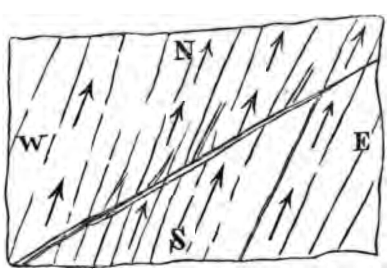
right angle to this bearing are the most productive in minerals. See diagram.



Again, even in the same metalliferous rock, without the least change in its character, composition, or structure, should the fracture have an undulating bearing, as shown in the following sketch, the masses of ore will accumulate more or less in the N.W. angles, the lode being left almost barren in the N.E. angles.



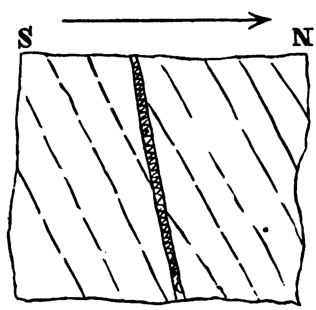
These facts are so general that they have been observed in Cornwall, Devon, Wales, Germany, and America. The following will illustrate the unfavourable angle of the rupture to form a mineral lode, which necessarily follows from the facts above explained*.



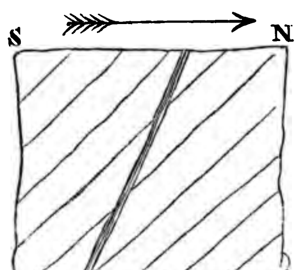
* Tin ore is however frequently formed in this angle, even in copper lodes, when in granite and the clay-slate on the flanks.

The following observations are taken from notes made underground in South America, Cornwall, Devon, Wales, Ireland, and Germany.

East and West Lodes underlaying North.—In granite, porphyry, and compact clay-slate, a good hard foot wall is a favourable indication, as far as the fracture is concerned; and in exploring this wall, however small and poor the joint or lode may appear, it is the safest to follow, and will lead ultimately to the greatest deposit should the rock be of a metalliferous character. A broken foot wall and a hard smooth head wall are unfavourable indications to produce large masses of ore. It is generally observed that when the jointy structure and the underlay of the lode occupies the angles delineated in the following cut,

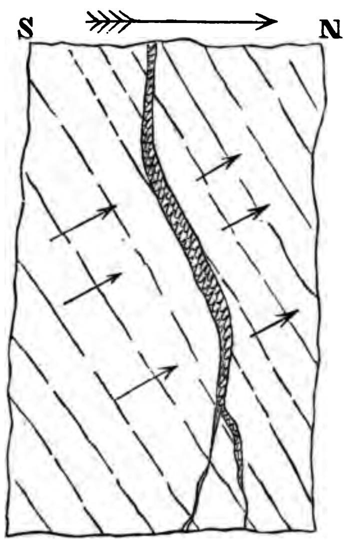


they are the best and most productive lodes. When these angles vary, the lodes vary also in quality. Lodes underlaying south in the same structure are productive on the back, and seldom continue to great depth. When the planes of the structure dip south, the lode also underlaying south, as shown in the diagram, the conditions are extremely unfavourable; there-



fore such lodes must have other very favourable conditions,

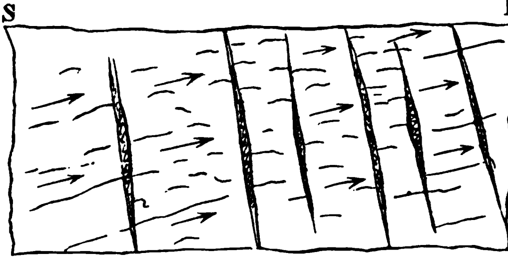
such as cross-courses, &c., to render them of value. These divisional planes of the crystalline rocks act in the same manner as the negative plate in the decomposing trough of a battery, on which the crystallization takes place at right angles to the plane; and the nearer a fracture becomes parallel to this angle, the more favourable it will be for the formation of crystalline matter, and the opening of the joints by the accumulated crystallizing forces. The following is a section of a lode in a porphyritic rock in South America.



The lode was very productive in the metalliferous part of the rock, where it was parallel to the structure, but became poor and dwindled into joints when varying from this angular dip. See section of the Marmato lodes. Lodes underlaying very flat southward, and to the north at similar angles, are unfavourable: the former is very showy on the surface, frequently producing small rich shallow bunches and good-looking gossans, thus leading many to imagine that they must be equally productive in depth as all other lodes presenting similar superficial indications. Generally speaking, lodes underlaying north from 10° to 20° from the perpendicular are the most favourable for continuous rich lodes to great depths. The parallel lodes of this underlay, in granite, porphyry, and com-

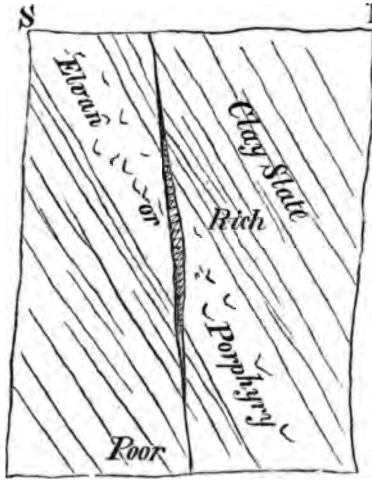
pact clay-slate, are productive in parallel bunches, as described below.

S N

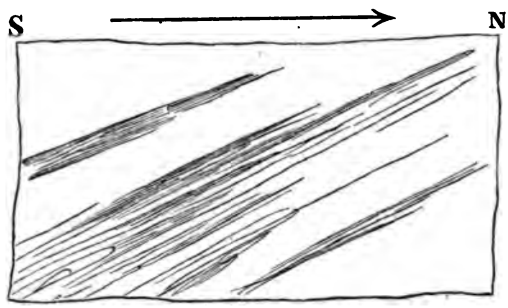


This parallelism of the bunches of ore is also observed in the line of bearing; the bunches getting gradually shallower as we proceed north. This angular rise of the molecular action northward varies in South America from 10° to 30°. In Cornwall the bunches of ore in the southern lodes are considerably deeper than they are to the north. Porphyritic veins in clay-slate are very productive of minerals, should the parent base be metalliferous. In a great number of the east and west copper lodes of Cornwall, as well as in many other districts, we find that an oblique intersection of an elvan has a very important influence on the production of ore. So much is this the case, that the ore has frequently been confined to the ruptured part of the elvan, like that of the lead ore in the limestone beds of Derbyshire, the other part of the lode being unproductive, with the exception of the filtration from the main bunch. See section.

S N

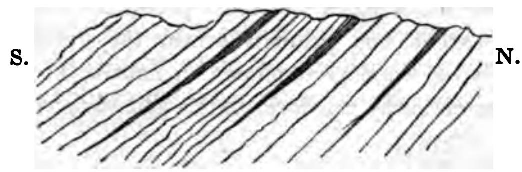


Slaty districts or schistose rocks are not favourable for the formation of east and west lodes. The mineral produce of such rocks is generally found running more or less in the same bearing. In the gneiss and micaceous schist we frequently find silver and lead lodes formed conformably to the bearing of the cleavage planes, and therefore more or less north and south. The shoots of ore in these lodes rise from the south at angles varying from 10° to 30°, as described in the sketch.



In the clay-slate part of the series, and more especially in the transition of the primary clay-slate into the sedimentary, the copper becomes formed like wedges and isolated slabs in quartz, within the limits of certain metalliferous bands, in the absence of lodes. These kind of formations are very common in the slaty rocks of North Wales.

Sometimes we find the mineral forced into the planes of the sedimentary beds, appearing to the uninitiated as lodes interstratified, or sometimes called contemporaneous veins, as shown by the annexed sketch.



These descriptions of mineral aggregation in the planes of the sedimentary beds, and also in the planes of cleavage, are the most deceptive kind of veins; frequently producing fine-looking gossan and rich ore near the surface, but dwindling into a mere joint in a few fathoms in depth, especially those inclining south.

The north and south lodes which are enclosed in the planes of the schistose rocks are not dependent on the immediate bounding rocks for a supply of ore. They are fed by branches coming in from the S.E. and S.W., but principally the latter; therefore fine bunches of ore may be found in such lodes enclosed in very uncongenial ground. When these lodes intersect the slaty bands obliquely, they then become influenced by the character of such rocks in the same manner as the east and west lodes; with this difference, that the mineral becomes formed in oblique shoots in the direction of the veins instead of crystallizing transversely.

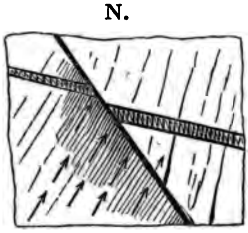
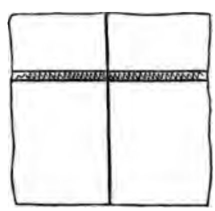
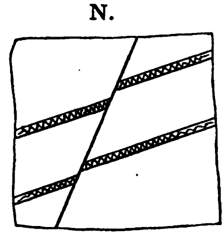
Roots and Branches of Mineral Veins.—The meeting of a number of veins either in depth or in a horizontal direction, is favourable for the accumulation of minerals, should they occur in a metalliferous rock under favourable conditions. But when such veins and branches unite in a hard unproductive ground they are of no avail, and more especially in the veins of fracture, or east and west veins. In east and west lodes the real feeding-*droppers* are the divisional planes underlaying north into the lode; those in the opposite side are, generally speaking, branches *from* the lode. The feeding-joints or roots, as it were, of the lode, are also on the south; those joints filled with ore on the north are the branches by which the mineral gets forced into the country from the lode. The south-east veins appear the best feeders of east and west lodes, and are sometimes the most productive portions of the lodes. In north and south veins the feeders are from S.E. and S.W., and the dispersing branches of these split veins are the N.W. and N.E. In the majority of instances we find the south-west branches in the north and south lodes the most productive, but only to a very limited extent, and principally near the junction. However, in studying these phænomena in nature, we must in all cases examine carefully the local twists and various contortions

produced by the constant molecular action of the elementary bodies.

Cross-courses.—The angular bearing and inclination of the cross-courses and flookans have a most important influence in the enrichment of lodes. Those running N.W. cause greater dislocations and accumulations of minerals than the cross-courses bearing to the N.E. To enumerate the mines in which these effects are observed, would be to note all the mines of celebrity in the world; therefore I must beg reference to the Plates for ocular demonstration.

The following diagrams represent, first, the most favourable conditions of the cross-course and lode,—the second moderate, and the third most unfavourable.

N. N. N.

S. S. S.

The north-west cross-courses frequently become sufficiently productive in mineral to work on, in the absence of the east and west lodes, and are called in Cornwall "Caunters."

The degree of richness will depend on the character of the rocks to the S.W. of the lodes, and the nature of the ground through which the cross-courses run from the south. Hence it becomes necessary to reflect well on all the influential circumstances, as various combinations of elements will give rise to many new and complicated results.

We frequently find the lodes enriched only on one side of the intersection, the opposite being comparatively poor. This is often produced by impermeable flookans; the mineral solutions being dammed on one side, the opposite part of the fracture being filled only with the substances which may exist on the other side of the intersecting flookan. Very large masses of ore have been formed by the horizontal oblique intersection of flookans with the lodes. The large mass of lead ore at Esgyr Mwyn

in Cardiganshire, and the immense deposit of copper ore in Anglesea, were produced by such intersections in conjunction with the local twist of the cleavage of the rocks.

Porphyritic or Elvan Courses, or Tabular Masses of Crystalline Rocks enclosed in Clay-slate.—When a fissure intersects clay-slate containing bands of granite, porphyry, or any other rock differing in character with the series, its contents become influenced by them; according to their composition and angular position, as illustrated in the diagram, page 102.

An elvan course inclining north and intersected obliquely by a lode underlaying north, will be the means of enriching the fissure at the intersection according to its conducting metalliferous quality, below which the lode seldom continues productive.

Many miners call any description of granular rocks differing from their killas Elvan, and thus often lead to erroneous conclusions. The productive "elvans" are porphyritic or granitic veins, which, when intersecting a series of clay-slate, become equal to the junction of granite for supplying the metalliferous elements; hence real "elvans" are favourable indications when found in good angular positions.

One of the most noted examples of the influence of an elvan course may be seen at Great Wheal Alfred. This rock runs from S.W. to N.E., underlaying north; the lode intersects it obliquely; while in the slate, on the eastern side, it contained mineral in moderate quantity; but in approaching the elvan it became much richer, and yielded sufficient ore to afford a profit of £140,000. After quitting the elvan on the western side, the lode became poor, and eventually the mine was abandoned as unproductive.

It is also frequently observed that all the lodes intersecting such elvans are more or less productive at the intersection, and become poor beyond them, showing most clearly their influence in the filling of the ruptures with minerals. In the event of such lodes meeting and intersecting similar elvans in their linear direction, or with productive cross-courses, they again become available by means of distinct conductors, which has been the case at E. and W. Alfreds.

Ironstone courses.—These ferruginous hornblendic rocks are

not productive *per se*, but their angular position and compactness frequently cause the enrichment of lodes by damming up the contents of a series. A wide "ironstone" course, like that seen at "North Pool," and also South Roskere, inclining north, renders the lode productive in the upper part of the intersection, but completely cuts off all supply from the under part of the lode. Should such an "ironstone" mass happen to incline north and bear E. and W., it is extremely unfavourable to the production of ore in lodes intersecting it. If the ferruginous rock form a band enclosed in the cleavage of the series and run N.E., masses of ore will be found in the lodes intersecting it, like those of Holmbush, on the upper side only, the amount of which will depend on the rocks and cross-course situated on the western side; below which large masses of ore are seldom formed.

Oblique trunks of Minerals.—Oblong masses of minerals are frequently found aggregated in the midst of granites and limestone rocks, and often in slaty districts.

The "*Carbonas*" of St. Ives Consols are formed by means of numerous small veins like roots from the south, converging into one grand trunk of about 10 feet diameter, growing or extending towards the N.E., at an angle of about 8° from the horizon, surrounded by the granite*. Indeed it would be an endless task to describe all the variety; therefore I must beg reference to the accompanying Plates and the facts *in situ* for further information on this interesting and truly important subject.

CHAPTER XVIII.

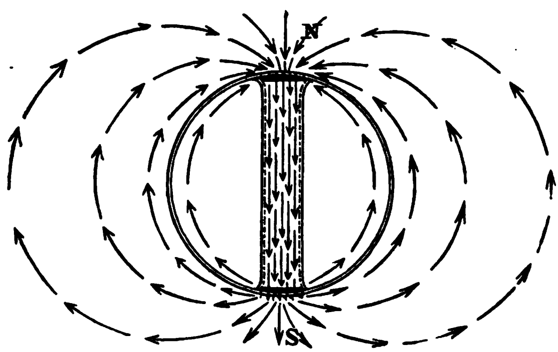
RECAPITULATION.

In the preceding chapters I have endeavoured to reduce all our observations into a system conformably to the well-known laws of terrestrial physics, and thus concentrate the scattered rays of

* The above is a tin mine. Tin ore is frequently found sufficiently productive in veins running in the direction of the grain, *i. e.* N.E.

useful knowledge which have been obtained from time immemorial, so as to render them useful to our industry, and especially to mining; the diffusion of the many important discoveries amongst a mass of untenable hypotheses, having hitherto rendered them uninviting and of no avail to the progress of real geological science.

First.—It has been shown that the power we call magnetism is universal, and that our globe is a great magnet, with the poles of divergence and convergence placed in its axis, as described in the diagram. The enveloping force rises out of the antarctic region

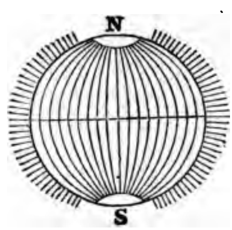


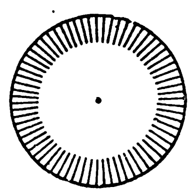
and passes through the earth, sea and the atmosphere towards the equator, and thence to the arctic region to complete the known circuit of power. Hence the curves of magnetic force not only imply the directions of the force which are made manifest when a little magnet is placed amongst them, but the lines of power which connect the poles and the permanent bonds of the elements of the terrestrial sphere. The more closely we examine the laws of magnetism, and particularly as they are presented to us in their terrestrial operations, the more surprising will their general influence appear to be. We learn by careful research that gravitation and electricity are the effects of the same great cause, which is ever busy in producing the necessary conditions of change in the earth to suit the wants of animated nature. Every substance is under its immediate and constant influence; the rocks, seas and all the minerals found therein are kept and moulded into exfoliated concentric spheres and arranged according to their respective densities by the terrestrial magnetic

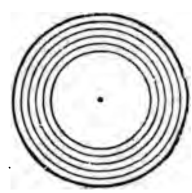
power, and the vegetable and animal life controled by its radiant force, called by Dr. Faraday diamagnetic. All gases and vapours necessarily ascend by the repelling force of the tension of the denser bodies forming the nucleus.

The system of spherical magnetic forces, arranged according to their densities and the substances with which they are combined, necessarily causes a great tension from pole to pole, the disturbance of which in one part is accompanied instantly by a disturbance of the tension in another part. The tension of water is greater than air, hence a bubble of the latter will ascend in the former. The uniformity and direction of the natural magnetic stream may be altered locally by the presence of a substance capable of transmitting a concentrated stream of the force like a magnet, and thus rob a large amount of the feeble currents in its vicinity; and should the disturbing agent not be capable of movement so as to conform to the natural direction of the force, a local bend will be produced.

Secondly.—We find that the structure of the crystalline rocks is not alone governed by the power of cohesion or aggregative attraction, but likewise by the great polar force, thus producing beautiful geometrical divisional lines in the primary base, as exhibited by the following circles:—





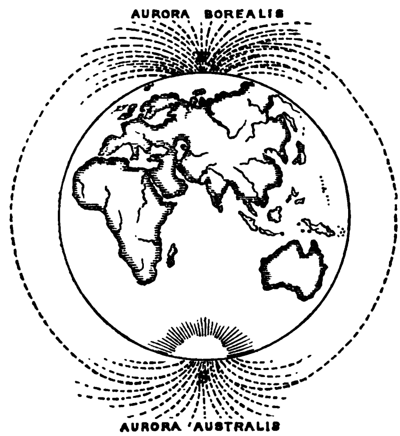


The first circle represents the polar lines of cleavage, with the external radiant repelling actions (diamagnetic); the second circle, a section showing the radiant planes of cleavage consequently formed by a compound of polar and radiant forces.

The third section indicates the concentric arrangement of fluids, or the terrestrial spherical exfoliations. These kind of divisions are frequently impressed on semi-aqueous crystalline matter. Hence the cleavage planes of the primary rocks are not mere local phænomena, but an universal structure, a polar

and radiant grain, formed from pole to pole, produced by the permeating action of the magnetic force, through which the subterranean substances are conducted, and the liberated gases escape.

Thirdly.—The primary film forming the base is a compound of crystals formed from aqueous solutions, and they retain a portion of the mother liquid. These are constantly subject to decomposition and recomposition, and the formation of many compounds in their circuit of activity, by the constant influence of the ever-acting polar force, and the surrounding sea of saline elements. The unequal degrees of aggregation cause variation in the surface; hence some parts protrude above the surface of the ocean and form dry land, whilst other parts are depressed, as seen in the following figure:—



The above sketch will also show the pointed configuration of the island and continents towards the south, arising from the action of the oceanic currents which are propagated from the south to the north by the great polar force.

Fourthly.—It is made evident that the polar splits and transverse fractures which are observed in the crystalline rocks, and their superincumbent sedimentary series, are produced by the polar tension; and that all description of crystalline veins have been formed by the progressive opening and filling of the ruptures by the internal solvents in the intersecting rocks, accord-

ing to their respective composition. These mechanical and chemical actions being the effects of the subterranean polar currents, not only fill every fissure and vacuity with solvents, by which crystals are formed, and swell open the joints by their growth, but they cause also new fractures and dislocations, according to the local physical conditions. This gradual opening during the growth of the crystals from the sides, accounts for the isolated masses of the bounding rocks found in them, and frequently in angular masses separated horizontally from the bounding walls. The east and west being veins of fractures are supplied with elements transversely, whereas the meridional splits are filled longitudinally in the direction of the force.

Fifthly.—The order of the "heaves" or dislocations has been explained, and also the conditions favouring the accumulation of minerals, and the rocks which are found most congenial to the production of different descriptions of minerals in all parts of the world. I have brought forward abundant examples to prove that every mining district has its conducting metalliferous channels, cross-courses, or feeding pores. It is of great importance to bear these facts in mind, to avoid being misled with the notions of supposing that a lode found to contain a rich mass or masses of ore in one place should be equally rich miles off in the direction of the rupture, although in barren rocks; which ideas are too often encouraged.

Sixthly.—I have endeavoured to connect those vague indications applied by old miners in their operations and reduce them to a general principle for the guidance of the intelligent miners. I trust the increased practical experience in their daily avocations and habits of observing, with the aid of the principles herein propounded, will enable them to form a more correct judgment of ground, and considerably reduce the present amount of useless and expensive explorations, and lead them with more certainty to new discoveries.

The more careful these investigations are made, the more convincing and satisfactory are the results; therefore these great principles of polarity, in combination with the various composition of the rocks and their structure, may be safely applied to any mining district in all parts of the world. These laws of geology and magnetism are therefore of vast importance to the practical miner and engineer; and the elucidation of the subject

to the furthest practical extent, and suitable to the capacity of ordinary miners, is the greatest desideratum which now remains in the art of mining, since the operations carried on for the discovery of the masses of ore contained in mineral veins and metalliferous rocks, cavities, &c., not only constitute one of the heaviest expenses of mining, but it is the vague and precarious result of these trials which chiefly stamps the proverbial character of hazard and uncertainty which is attached to the pursuit. I therefore trust that the foregoing chapters, with the aid of the numerous accompanying Plates, illustrating the principal mineral districts, will tend to simplify the science and enlighten those who are interested in the subject, and remove in part that embarrassment and complexity which have hitherto impeded the progress of this department of geological science.

CHAPTER XIX.

ON THE POLARITY OF EARTHQUAKES, AND THE NATURE OF THE CONTENTS OF THE MAJORITY OF VOLCANOES.

Those who have had no experience in these phænomena are labouring under the impression that earthquakes are the effects of an incandescent nucleus, *i. e.* the violent action of molten matter in its attempt to burst and break through the thin shell by which they confine it within, and on which it is supposed the Creator has placed the organic kingdom after it became cool. We have already pointed out the inconsistency of such a state of things; and it is difficult to conceive how any rational being could for one moment encourage such notions, as to imagine that a globe of water, in combination with other substances with which it is combined, could have retained within it a permanent globe of molten matter. The idea is truly monstrous. It would never have been thought of, but for a few, and comparatively speaking, insignificant holes, which occasionally become inflamed by strong chemical activity, and thereby melt a portion of the rocks during the period of the inflammation. With equal reason the clouds may be considered molten matter, because we see lightning and fiery meteors amongst them occasionally. These pimples of eruption

would be scarcely perceptible on a globe of 3 feet diameter, and probably, with few exceptions, would not penetrate to the depth of the varnish coating; besides nine-tenths of those observed are aqueous, and not igneous eruptions. Having studied them from the magnitude of the Andes to the diminutive dimensions of mole hills, like those of Turbaco near Carthagena, I have found them all, without exception, similar in character, viz. the effect of local chemical action; the great ones being situated along the lines of the meridional splits, and the secondary eruptive pores on the transverse fractures. The sudden ruptures, as well as the occasional rapid expansion of the gases generated, produce a vibratory jar, which being propagated along the cleavage planes or through the pores of the rocks, give rise to superficial oscillations, and thus cause earthquakes and subterranean thunder for thousands of miles from south to north. The shock of the earthquake in Chili, 1822, was felt simultaneously throughout a space of 1200 miles, from south to north; the lateral oscillations being confined to narrow bands. The following are a few registered by the author in South America:—

1834. Jan. 20.—Violent shock from Chili to St. Martha in a more or less meridional direction; caused great damage in the line of its maximum force. Its meridional disturbances were felt over a space of 1500 miles of linear measurement; but the transverse oscillations scarcely extended over 200 miles of land.

1835. Feb. 20.—Ditto, a great number, and continued more or less daily until the month of March.

1836. Jan. 4.—Slight shock from the south.

Jan. 8.—Ditto.

On the central Cordillera, from four to five shocks almost daily, from the 1st to the 15th.

1837. Nov. 10.—A shock from the S.S.W., accompanied by subterranean thunder, after heavy rains.

Nov. 27.—Ditto, after a few days' intense heat.

1838. June 19.—Two violent shocks; no oscillations; the ground appeared to heave up.

Aug. 9.—Sounds heard in the mines, passing in the direction of the cleavage from south to north; no oscillations; the magnetic needle much affected.

1838. Aug. 11.—Shock accompanied by a very loud explosion, apparently from the volcanic vent of the Paramo de Ruez.

1839. May 28.—A severe shock, continued for nearly a minute.
Sept. 21.—Ditto.
Sept. 22.—Ditto.
Sept. 28.—Ditto.
All in the usual direction, from south to north.
Oct. 15.—A great number of shocks during the last few days. The quantity of rain fallen last month exceeds that of any month in the last three years, viz. $15\frac{1}{2}$ inches. Natives consider earthquakes to follow the extremes of wet or hot weather.
Nov. 28.—Ditto.
Dec. 13.—Three very violent shocks from the S.S.W. to N.N.E.

1840. Jan. 2.—Strong shocks from the south.
June 12.—Ditto, the oscillations confined to very narrow limits.
Aug. 22.—A sharp shock from the south.
Dec. 11.—A severe shock from the south, lasted fifty seconds; several houses thrown down in Antioquia in its line of bearing.

1841. Mar. 12.—Slight shocks from the usual direction.
Mar. 19.—Ditto.
June 1.—Ditto; the magnetic needle much affected.
Sept. 8.—A severe shock.
Sept. 14.—A slight shock.
Sept. 30.—Ditto.

The whole of the above, without exception, were from south to north, and oscillating from east to west. It will therefore be observed that earthquakes are subject to laws of action as uniform as other natural phænomena.

I could add also more recent observations showing similar uniformity; and on reference to the description given of the earthquakes which occurred in Chili in April last, we find that they were propagated from the south and terminated on the coast of the Caribbean sea.

In 1797, the district around the volcano of Tunguraqua in

Quito, during one of the great meridional shocks, experienced an undulating movement which lasted four minutes. At the foot of the Paramo the earth was rent open, and streams of water and fœtid mud with fish poured out, overflowing and wasting everything. During several of the eruptions which have taken place since the year 1822, on the western coast of Chili, some were seen which were followed by great whirlpools, as if the sea was pouring into cavities of the earth. The volcanoes of Nicaragua, in Guatimala, during their activity, are commonly attended by whirlpools. Had there been such an igneous nucleus as the one assumed by the Plutonists, covered only by a thin crust, what would be the consequence when the sea happens to pour into it? There would certainly follow some awful catastrophe; but we are happy to state no such convulsions have occurred. Aqueous products and muddy matter are more common than lava or melted rocks; and we find that they generally contain putrid fish of the adjoining sea or lakes, as the case may be. Hence, if we take the products, their effects, and linear actions into consideration, we have strong evidences in favour of considering the whole phænomena due to electro-magnetic action. When we examine the volcanoes in Europe we find them governed by similar laws. Etna and Vesuvius are situated on the same meridional line.

Upon glancing at any of the maps of the world, or a globe, it will be observed that the whole of the volcanic groups of the Pacific, the Atlantic, &c., are ranging along the main S.W. and N.E. splits, or their transverse fractures.

With respect to the products of volcanoes, we find them all more or less alike. The Javanese volcanoes frequently discharge large quantities of acidulated waters, even in torrents, with sulphurous mud, being probably the effects of the decomposition of sulphuretted hydrogen gas. Torrents of water issued out of Vesuvius during the eruption of 1631, and from Etna in 1755.

In regions such as Iceland, where the products of the volcanoes have been carefully examined, the same law prevails. They may be traced from a mere spring to a gigantic cone. Professor Bunsen has pointed out several which he considers to be now in progress in Iceland. "The Icelandic mineral springs," he remarks, "to which belong all the system of geysers, may be di-

vided into two main groups, according to their chemical properties, one of which comprises the acid and the other the alkaline silica springs." Sir George Mackenzie mentions that the deposits from geysers extend to about half a mile in various directions, with a thickness of more than 12 feet. The leaves of birch and willow are fossilized, every fibre being discernible. Grasses, rushes and peat are in every state of petrifaction. Dr. Black found the waters from the geysers, both hot and cold, to contain soda, alumina, silica, chloride of sodium and sulphate of soda. The hot springs of India, not situate in a volcanic country, contain from 20 to 30 grains of solid matter in a gallon; silica, chloride of sodium, sulphate of soda, carbonate of soda, pure soda, &c. In short, the eruptive pores, from the size of a small spring to that of the magnitude of a volcanic crater, vary only in their dimensions, and not in character, and are the effects of active local conditions generated by the elements of the sea and the crystalline base; their periodical activity being governed by physical causes resulting from polar tension. The thermal group to which the geysers belong are from south to north, bearing slightly to the E., 20 miles long, and almost parallel with the chain of Hecla, and with the general bearing of the cleavage and splits.

The water of the Great Geyser contains, according to Dr. Sandberger's analysis, silica, carbonate of soda, carbonate of ammonia, sulphate of soda, sulphate of potash, sulphate of magnesia, chloride of sodium, sulphide of sodium, carbonic acid, &c. These compounds and their gases must decompose some of the rocks they pass over, and vary in effects under different conditions, as already described in the previous chapters. There are about 175 known active volcanoes; with the exception of five or six they are situated near the sea, or at least are more or less connected with the saline waters of the ocean, as already explained in the preceding chapters; there are scarcely five of them purely igneous, producing only melted rocks or vitreous lava. Mud volcanoes and gaseous exhalation are the most numerous.

With respect to those which discharge gases, they are not only found connected with volcanic regions properly so called, but also in loealities where the cause of the phænomena may be examined, so as to remove any doubt on the subject. Coal districts

discharge such continuous streams of carburetted hydrogen, as to afford a sufficient supply for economical purposes, giving light and heat in the United States, in China, and near the Caspian. Some of our northern collieries often evolve sufficient gas and maintain flames for many years. No intelligent man would attribute the formation of such a gas to the action of subterranean fires, however analogous the gas may be to that produced in our gas-works. We find such gases are abundantly produced from certain coal beds and carbonaceous shales, the result of a decomposition of those bodies by which a portion of the constituent carbon and hydrogen is evolved in a gaseous state. The main faults and the fractures, or any other passage, would permit the escape of the gas as it becomes generated below, and on being ignited, must necessarily char, or even melt certain descriptions of substances*. These gaseous emanations are not confined to the coal districts, but are also seen in the pitch lakes, naphtha and bituminous springs that issue out of the primary crystalline rocks, *i. e.* not from organic matter, but from the sources of the primary elements. It would occupy too much space to detail the products of the numerous eruptions of mud and gases showing their identity, and that they belong to the same phænomena as volcanoes, being the effects of the chemical activity and various decompositions of the compounds, and not internal fires; and as the subject comes under so many different heads and aspects, and so connected with the general principles of the physical operations of nature, we shall conclude this chapter, and proceed to show, not only the instability of the size and form of our dry lands, but also that the whole surface changes and disappears in long intervals of time.

* The Kimmeridge clay of the Weymouth coast, in which there is much shale in places so bituminous as to have been distilled for the bitumen in it, offers from time to time a good example of the "burning" of a cliff from the decomposition of iron pyrites amid bituminous shale by the action of the weather. The heat generated has been occasionally so great as to fuse some of the clay or shale.

CHAPTER XX.

THE NORTHWARD AND UNDULATING MOVEMENTS OF THE EARTH'S SURFACE *EN MASSE* BY THE CONSTANT PERMEATING AND CIRCULATING FORCE OF THE ELECTRO-MAGNETIC CURRENTS FROM SOUTH TO NORTH.

The phænomena to which we shall now direct attention will remind us that everything in nature is in a perpetual state of change. There is nothing permanent but the laws and the harmony of the movements of the celestial system, and probably the dimensions of the heavenly bodies. If we regard the conditions of the beautiful and varied organic covering of our globe, the certainty of constant changes is ever before us. The primary elements feed vegetable life, this again nourishes the animal, and both perish to feed the future plant, and thus continue to supply the wants of successive generations.

From the apparent quiet and regular succession of natural events to which we are accustomed, and the repugnance we feel to the idea that it is possible for the common course of nature to change the general appearance of the surface without causing interruptions, we might, without due investigation, almost persuade ourselves that the physical features and conditions of the globe possess an unchangeable character. Indeed the general phænomena of nature daily before our eyes are often those which are considered the least attentively. In looking at an extensive forest for a hundred years, it would appear to a superficial observer that he was viewing the same identical substances all the time, yet there is no truth more certain than that the whole, or nearly so, would entirely change in the interim. Continents are continually changing their physical aspects and configurations, emerging and submerging from the level of the ocean, and moving in masses, unobserved by the millions of animated beings who have their existence on them. We are, as it were, like parasitical insects placed on a film which is equally subject to decay. Generation after generation disappears, while others are taking their place; and so gradually and imperceptibly are these effected, that without reflecting a little, and comparing the past with the

present, we almost look at things as if they had been always in the same state. So familiar and reconciled we become to the altered conditions during the fleeting moments of our mortal existence, that the past is soon forgotten, and man, who is linked to these renovating laws of nature, too often forgets his final destiny;—today he might be a monarch of a great nation, but in a very few years he must return into the soil; giving back the substances which are to serve the use of generations to the end of time. Whilst the land and its organic covering become thus subject to perpetual changes, the element, which has been hitherto considered as the type of mutability, remains constant in its general character and contents; thus verifying the sublime apostrophe of Lord Byron to the Ocean:—

> "Thy shores are empires changed in all save thee:
> Assyria, Greece, Rome, Carthage, what are they?
> Thy waters washed them while they were free,
> And many a tyrant since,—thy shores obey
> The stranger, slave or savage; their decay
> Has dried up realms to deserts,—not so thou!
> Unchangeable save to thy wild wave's play;
> Time writes no wrinkles on thine azure brow,—
> Such as creation dawn beheld, thou rollest now!"

The accumulated evidences obtained from all parts of the world, not only prove that our present dry lands have been subject to great changes, but also show us the instability of the present conditions of things, and that the continents change their outlines in long intervals of time.

These variations, though hardly sensible from one generation to the next, become so great as to alter, not only the relative height of dry land, but also the latitude and longitude in the course of centuries. The surface of the higher lands is daily worn away by rains, and the mud, sand and organic remains are carried down to the valleys, &c., preparing sedimentary rocks for future generations.

The observations made on the changes in the relative level of the sea and the lands on the coast of South America, both in the Atlantic and the Pacific, abundantly testify that they take place without the aid of earthquakes by slow subterranean forces, and that these forces oscillate and act as insensible as those which have affected the temple of Serapis. Hence the coasts

are perpetually altering, either by the shifting of the water-line, by encroachments of deltas or the overflowing of the land by the sea. The ocean currents, being constantly from the south, and bent by the configurations of the continents, become very active geological agents in the leveling and accumulating of the sand, mud and organic remains. Again, by a gradual protrusion of the crystalline base, into a ridge, like that of the Isthmus of Panama (see Plate), it would cause great physical changes. In the first place, the separation of the two oceans in such a position and at a right angle to the current, must cause a high tide on the south, and destroy it on the north, and thus alter the temperature of the currents in the northern hemisphere, and consequently the climate. In consequence of the warmth of the Gulf-stream, we have on the west coast of Europe a much milder climate than corresponding latitudes in America and Asia; the depression of the Isthmus of Panama would reduce the temperature, by bringing in the cool streams of the South Pacific.

Two hundred and fifty years ago Sir F. Drake with his fleet entered Albemarle Sound through Roanoke Outlet, which is now a sand-bank above the reach of the highest tides. Only seventy years ago it was navigable by vessels drawing twelve feet of water. A comparison of the present charts with those of 1775, shows not only that these shoals are increasing, but that the chains of islands are undergoing process of change. Such changes are now so familiar to geologists that they are unequivocal established facts. The gradual sinking of the western coast of Greenland, and the equally slow and gradual movement taking place throughout a large part of Sweden and Finland, and many other parts in the northern hemisphere, where earthquakes are seldom felt, are ample evidences of a more uniform and constant force than volcanic disturbances. How much more satisfactory and consistent with the ordinary laws of nature is it to regard these grand operations as the necessary consequence of the polarity of matter and crystalline forces, than to suppose them as resulting from a series of convulsions, regulated by no laws, and reducible to no fixed principles!

In fact, the changes of the South American coast are so rapid as to require a constant survey to render the charts correct in their longitude and latitude. The surveys of the present century show a more northerly latitude than the last. Indeed, in

making comparisons between the ancient latitudes of numerous places in South America with recent observations, we find an average difference amounting to about twenty minutes in favour of a more northerly position. These changes in the crystalline film, which is permeated by the polar forces already described, are the necessary consequences. We have shown that the sea and all matter move from south to north, and that these great movements observed in nature may be imitated by means of an artificial sea, with an electro-magnetic axis. A crystalline film placed between two poles will receive new crystals from the liquid at the negative pole, whilst the same amount of the film will decompose and dissolve again into the liquid at the opposite pole; and thus the floating substance becomes perpetually propelled towards the positive pole, *i. e.* the south pole of an artificial magnet, which corresponds to the north pole of our globe.

Granting these mutations in the southern hemisphere, it may be said that they cannot have been going on during the last thousand years in the northern hemisphere; otherwise they would have been detected by astronomers, as the latitudes of places must have varied.

In comparing Ptolemy's observations with the present we recognize great discordance. Even at the beginning of the last century the position of places could not be depended upon within 20 minutes. Let us suppose that the position of a place was known a hundred years ago, and that it was situated exactly in the equator; in comparing the same point at distant intervals of time with the same celestial objects, we find a difference amounting to a measurable quantity; and this difference is proved by astronomical observations to be in one direction. Consequently, in order to denote the latitude, or rather to preserve it in the same relative spot, the position of the celestial objects must be altered. This change is called the precession of the equinoxes. To account for this movement it has been assumed that the axis of the globe is continually altering its relative angular position in space, which apparent movement during the historic period has been *northward.* The amount of this motion, by which the equinox appears to travel, is 50 seconds per annum, producing a change along the meridian of about 19 seconds. This relative change destroys, in the lapse of a moderate number

of years, the arrangement of the catalogues of stars, and makes it necessary to reconstruct them. Since the formation of the earliest catalogues on record the place of the equinox has retrograded about 30 degrees.

When the above hypothesis of the precession was propounded, the earth's surface was considered as a fixed and immoveable mass. So little was known of the phænomena of geology, magnetism, &c., that they were not consulted; hence a change of the whole globe appeared necessary to account for the observed variation. The cause of such a movement has been attempted to be explained by the assumed geometrical forces. It would be easy to analyse the hypothesis; but as we have questioned the very foundation of the principle on which it is founded, we need not dwell on it here, but simply state, that the movement of the surface of the globe northward accounts for the above effect in a more convincing manner, and more free from intricate computations, than the *geometrical physics* now used in astronomy. Besides, the supporters of the theory leave a residual phænomenon equal to about ten seconds unaccounted for, and another movement in the ecliptic; hence we have abundant proofs by celestial observations of terrestrial changes in a northerly direction. It may be argued, that if the masses of dry land, which are now situated near the north pole, containing organic remains belonging to the tropics, have been propelled there by such a slow northward action, it must have taken some thousands of years since they were in the torrid zone more than we can admit according to our chronology. With respect to our chronology, it is not well defined, *i. e.* not a demonstrable quantity; it is a mean of a compound composed of uncertain quantities, therefore necessarily an uncertain amount. Not one of the chronological records was considered sufficiently certain to be adopted —the Egyptian and Chinese were left out—therefore it is useless to enter into this question; besides, it matters not to our creed whether the globe was created 7000 years or 60,000 years ago; time cannot make any difference in a faith which is founded on too firm a foundation to be shaken.

Plato said that the world changed its superficies in every respect; that the heavens and the stars changed and reversed their movements by time, in such way that the east appeared to be-

come the west. We find also the Egyptian priests acquainting Herodotus, that from the commencement of the dynasty of their kings (which, according to their computation, extended to more than 11,000 years) the sun had apparently changed his course in the heavens four times.

We can easily conceive that a country like Australia, which is now south of the tropics, if brought up to the northern hemisphere, would cause the sun to appear to rise on the left instead of, as in the former situation, on the right: probably such appearances were the origin of the above notion of the Egyptian priests.

The observations of the ancient philosophers have been lost in the lapse of ages; however, we have great advantages in our present investigations; the records of the past have been laid down and preserved by a power beyond the reach of human control: we may recall the past and anticipate the future, by means quite independent of the conflicting and imperfect evidences of human record, and reason on them according to the existing natural laws.

With regard to the actual time since the creation of the system, that is a question totally beyond our reach, and is as useless as it is unreasonable for us as finite beings to enter upon such a subject; all that we can legitimately speculate upon is the nature of the dry crust we call land, and the forces that control it. The whole of the dry land becomes oxidated as it arrives within the influence of the north pole; and unless a corresponding dry land continues to rise from the southern hemisphere, towards which the living system may retrograde, the world must come to an end, independent of the existence of the globe itself as a body in space. How long these natural operations have been going on is not in our power to conceive.

There are many philosophers who admit in its full extent the doctrine of final causes as evinced in the structure of a plant or an animal; or, in other words, who really grant that all the various parts and organs conduce to one definite purpose, having a beginning and ending; yet they are reluctant to allow that the earth itself is under any other guidance than an irregular and confused igneous element. Every part of the surface of the globe is adapted to the wants of man, and the inferior creation

by which he is surrounded; it is not the result of chance, or of any imaginable fortuitous circumstances, but the production of a season,—it has its beginning and ending, like animated nature: the southern hemisphere is the spring of our terrestrial habitation, the equator its summer, the northern hemisphere its autumn, and the north polar basin its final dissolution.

CHAPTER XXI.

THE NORTHWARD MOVEMENT OF THE SURFACE PROVED BY THE CLIMATE OF THE LAND IN THE NORTHERN HEMISPHERE GETTING COLDER.

We have evidences of the progressive movement of the surface towards the arctic region in the changes of the temperature of the northern hemisphere.

Within the limits of the historic records we find that the climate of Europe has been getting gradually colder, and that the inhabitants of the north are continually retrograding southward. We mean here the annual *mean* temperature, and not the mere periodical cold or mild season. The character of the vegetation is the best test on this question. The first settlers in Iceland found extensive districts of that now dreary country covered with forests of birch and fir. They were also able to cultivate barley and other grain. At present the whole island is almost a naked desert, the native woods have totally disappeared, and the Icelanders have long since relinquished the practice of growing corn. The relics of the past in this island are few, but sufficient to prove its former habitable state. One of the most remarkable circumstances attending the discovery of Iceland is, that relics were found there which showed that it had been *previously* inhabited. The nature of these relics, which consisted of bells, wooden crosses, and books in the Irish character, induced the Norwegians to believe that those prior inhabitants were Christians, who gradually retired southward to Scotland and Ireland.

The most ancient of the Icelandic chronicles are not contented with mentioning the vestiges of former inhabitants; they distinctly state that there were actual settlements on the island previously to the Norwegian emigration*. They name Kirkinbui, one of the *warm* and *fertile valleys* that occur on the southern coast, as the residence of those *papæ*, as they called strangers, who deserted the island.

Greenland, according to most of the Icelandic histories, was discovered in 982, but it was then inhabited; and there exist letters patent of Louis the Debonaire in 834, and a bull of Gregory IV. in 835, which confers on the church of Hamburg, among other privileges, that of converting the heathen in Iceland and in Greenland, which at that period contained large populations.

The new settlers in Greenland had their bishops from Europe, and continued their intercourse with the parent state of Norway till the year 1418. The colony paid to the pope an annual tribute of 2600 pounds weight of walrus' teeth, as tithe and Peter's pence. The dreadful pestilence, called the *black death*, which in the middle of the fourteenth century depopulated all Europe, extended its ravages to Greenland. The colony was, from this and the increased severity of the climate, enfeebled, and soon after disappeared from history.

There was a country called Vinland within a few days' sail of Greenland, watered with rivers yielding abundance of fine salmon, on the banks of which were trees loaded with agreeable fruits, the temperature delicious, and the soil very fertile. Amongst the fruits were found grapes, which was the cause of their naming it the *land of wine*. It is impossible to shake the authenticity of the above circumstantial accounts of the Northmen; and it is likewise difficult to acknowledge their genuine character without admitting at the same time that Vinland was in Newfoundland.

Wine was made from grapes which grew formerly in the open fields of England and in the north of France, and there are ample proofs of a similar reduction of mean temperature in other parts of the continents of Europe and in North America. It is in the *northern* regions that we find relics of the past so abundant, and more especially of man and his works, and the remains of animals

* Lardner's Cyclopædia, Maritime Discovery, vol. i. p. 216.

subject to his control, and probably the greater part of these have disappeared, by the constant wearing away and oxidation of the land as it approaches the pole.

According to recent accounts, several subterranean stone labyrinths have been discovered in Lapland, Nova Zembla, Spitzbergen, and some of the islands lying near the coasts of Finland, particularly in Wiez, which is all desert, called by the natives Babylons*. Arabian coins are found in many parts of Russia, along the Volga, and northward even as far as the White Sea, all of which are of a date anterior to 1010†; thus showing that the different races gradually retrograde southward as the dry land advances northward.

When we descend below the surface and examine the remains of the past organic system now inclosed in the rocks, the proofs of the change of climate are much more decisive, and free from all the doubts arising from imperfect history. So striking has been the general northward action on the surface, that the effects have been long observed. In the northern latitudes beyond 60° we find the animal spoils of the southern countries and the marine exuviæ of the southern seas embodied in the rocks; but in the southern latitudes we find no remains of animals, vegetables, or shells belonging to the northern, but those only indigenous to the neighbouring land and seas. The sedimentary rocks of the northern hemisphere were, at a former period, during their deposition, exposed to hot climates, and gave nourishment to forests of luxuriant plants. In the superficial deposits of sand, gravel and loam, strewed over all parts of Europe, remains of Mammalia are discovered, among which are those of the elephant, rhinoceros, hippopotamus, bear, hyæna, lion, tiger, crocodiles, and others, consisting of genera now confined to the tropics.

At the period of the deposit of the Lias the vegetation was similar to that of the *southern hemisphere*, not alone in the simple fact of the presence of Cycadeæ, but the pines were also of the nature of species now found *only* to the *south of the equator*. Of the four recent species of Araucaria at present known, one is found on the east coast of New Holland, another in Norfolk

* Athenæum, part 190.

† Lardner's Cyclopædia, Maritime Discovery, vol. i. p. 169.

Island, a third in Brazil, and the fourth in Chili. With regard to the degree of analogy which the productions of different regions may be found to present with the fossil reliquiæ of the lower series of rocks, it is impossible to turn to Australia without observing most distinctly that the productions of that region have more than the average resemblance to the fauna and flora now found entombed in the northern hemisphere. In the coal deposits the proofs are equally striking that they were deposited in a climate like the southern hemisphere*. No coal except a recent formation of lignite and bituminous matter is found from the tropic of Capricorn southward, *i.e.* of the character and magnitude of our great coal formations; in a word, the whole of the deposits of the southern hemisphere are comparatively recent, whereas those of the northern are more or less ancient.

It is not merely by reasoning from analogy that we are led to infer a diminution of temperature in the climate of the lands now situated in the northern hemisphere; there are direct proofs in confirmation of the same doctrine. It is not in England or Northern France, but around the borders of the Mediterranean, from the South of Spain to Calabria, and in the islands of the Mediterranean, that we must look for conclusive evidence on this question; for it is not in strata where the organic remains belong to extinct species, but where living species abound in a fossil state, that the question can be subjected to the *experimentum crucis*. The fossils of the Subapennine hills, and their living analogues from the tropics, correspond in size; but the individuals of the same species from the Mediterranean are dwarfish, and appear degenerate and stunted in their growth, for want of conditions which the Indian Ocean still supplies. This evidence is not neutralized by any facts of a conflicting character; such, for instance, as the association, in the same group, of individuals referrible to species now confined to the arctic regions. Whenever any of the fossil shells are identified with living species at or near the equator, it is not in the Northern Ocean, but in the Southern that they must be sought.

In Chili, in latitude 36° S., the shells found on the tops of

* The description of the flora enclosed in the coal formation of England so exactly corresponds to that of the existing flora of the southern hemisphere, as to render the analogy complete, as also all other organic remains.

the mountains are those of the neighbouring sea. Those found on the hills between Suez and Cairo are similar to those of the Indian Ocean; and those that exist in the calcareous rocks of Egypt are likewise analogous to those living in the southern seas.

When geologists assumed an igneous globe undergoing refrigeration, to account for the former high temperature of the northern hemisphere, they imagined that the southern hemisphere indicated the same kind of change, *i. e.* from hot to cold; but it will be observed that the changes are quite the reverse.

The variable temperature on the surface of the globe is produced by solar radiation in connexion with the modifying effects of the atmosphere: we have no reason to suppose that climate and the organic kingdom have ever been governed by any other source of heat. In order to understand the general nature of the present climates from pole to pole, let a convex lens be exposed to the rays of the sun, the rays will be concentrated into the focus, and cause intense heat; the degree of heat depends on the number of rays collected and concentrated into the focus. If we expose a small point to this focus it would be intensely heated; but if, instead of a point, we place a large body in the focus, the heat would be diminished, and the nearer we approach the lens the less the heat.

Our globe occupies the focus of the atmospheric lens, illustrated in Plate III., and thus prevents the concentration of the sun's rays into one point. In the equatorial region, when the sun is in the zenith, if we ascend to the height of 20,000 feet, instead of finding it hotter as we rise, we get into colder regions, *i. e.* perpetual snow. Hence it follows that one planet may be near the sun, and another placed at the confines of the solar system; and yet both possessing equal temperature on their surfaces, by proportioning the diameter of their atmospheric lenses to that of their respective bodies. Therefore to say that Venus *must* be intensely hot and that Saturn is in the region of eternal snow, is a mere assumption, unsupported by analogy. Some attempts have been made to show how the globe may have become hot and cold by its probable exposure to the effects of intense stellar radiation in passing through the milky way; but such speculations are flights of fancy, and unworthy of atten-

tion. There has been too much dependence placed on celestial observations and assumptions already for the progress of geology. If we would speculate to any purpose on a former state of our globe, and on the succession of events which from time to time have changed the condition and form of its surface, we must confine our principal inquiries to the results or effects of terrestrial physics, and not attempt to solve the problems by reference to celestial objects; for if we differ so materially on those points which we can handle, it is not probable that we can decide by referring to objects so much beyond our reach.

We shall give a few examples of some points used by geologists for their guidance in theoretical researches, founded on astronomical observations, which are not only doubtful, but proved incorrect. It is said that the moon turns on her own axis, because she is an oblate spheroid, notwithstanding that she always presents the same face towards the earth. That a body revolving round a centre, and continuing to present *the same face to that centre*, should rotate on an axis situated parallel to the revolving axis, is physically impossible. Yet it is maintained, and absolutely stated in our astronomical works, that the moon rotates on her axis.

Suppose a balloon were to float around the earth, it would continue to present the car towards the centre, in the same manner as a vessel would her keel in sailing; yet neither can be said to have rotated on their axis in making the circumnavigation*.

There is another idea propagated respecting this body, viz. that she has no atmosphere, because we do not observe any refraction during the occultations of the stars. If the moon is enveloped in an atmosphere, the angle of refraction would be between the moon and the star, and that would, on impinging on the moon's surface, be reflected towards the earth. If a ray of light be successively transmitted through several transparent media having different refracting powers on one side, and reflected so as to pass through similar media on the other side, its emergence from the last of these media will take a direction

* The governor balls of a steam-engine make analogous movements, and in looking at them it will be at once perceived that they merely revolve around a centre, and do not rotate on their respective axis.

parallel to that which it had when incident upon the first of them. In this case the several refractions which the ray suffers in passing through the media on the one side is compensated and neutralized on the other, so as to produce, on the whole, no deflection of the ray from its original course. "The angle of incidence is equal to the angle of reflexion." The reason why we observe the refraction of the rays in our atmosphere is, because we are exposed to *one* angle only, *i. e.* that of refraction, owing to our being *within* the spherical media. Yet we are told the moon has no atmosphere, because she does not show signs of refraction. Persons have actually attempted to describe the geological features of the moon, being at the same time comparatively ignorant of the nature of the ground on which they stand! If the above simple questions are in such a confused state, and so easily demonstrated at a distance by the aid of mathematics, what are we to expect from the geology of the moon?

The changes of climate have been attributed by some to a greater eccentricity of the orbit formerly than it has at present. But even the eccentricity of the orbit is a doubtful question; the only proof brought forward that the orbit is eccentric is the variable diameter of the sun. The atmospheric lens not only refracts the rays when not in the direction of the radius, *i. e.* in the zenith, but also augments the size of bodies, such as the sun, the maximum size being in the horizon and the minimum in the zenith. According to a series of observations made by the author for 13 years within the tropics, the sun's *apparent* diameter is throughout the year the *same* when measured in the zenith; therefore its observed variable diameter is an *optical deception*, and not from any eccentricity of the orbit. That this is the case must be well known to those who have taken observations in the southern hemisphere with delicate instruments, and especially when the diameter of the sun formed an important amount in the measurement. See Plate III.*

* Santa Ana, N.L. 5° 10′ 0″. The sun's diameter, according to direct observations taken in the meridian from the south tropic to the north.

South tropic	<61°	22′	37″	altitude.	31′	30″	diameter.
Equator	84	50	0	„	30	45	„
Zenith	90	0	0	„	30	36	„
North tropic	71	35	20	„	31	12	„

The following measurements exhibit the apparent variation of the sun's diameter

To return from this digression, we find that the variable nature of climates from pole to pole arises principally from the obliquity of the rays and the height from the sea, and not from internal heat; therefore we can only account for the changes of climate indicated by the organic remains by changes in the relative position of the dry land and the sun's rays.

"However constant," says Sir C. Lyell, "may be the relative proportion of sea and land, we know that there are constantly some small variations in their respective geographical positions, and that in every century the land is in some parts raised and in others depressed. By these ceaseless changes the configuration of the earth's surface has been remodelled again and again since it was the habitation of organic beings, and the bed of the ocean has been lifted up to the height of some of the loftiest mountains. The imagination is apt to take alarm when called upon to admit the formation of such irregularities in the crust of the earth after it had once become the habitation of living creatures; but, if time be allowed, the operation need not subvert the ordinary repose of nature, and the result is in a general view insignificant, if we consider how slightly the highest mountain chains cause our globe to differ from a perfect sphere. Chimborazo, though it rises to more than 21,000 feet above the sea, would be represented, on a globe of about six feet diameter,

in the plane of the orbit during its daily apparent path, from the rising to the setting; the latitude of observations and the sun's declination being equal.

		Diameter.			Diameter.
The sun rising	$< 0°$	32′ 55″	Noon S. in zenith	$<90°$	30′ 36″
,,	15	32 35	,,	75	31 2
,,	30	32 18	,,	60	31 30
,,	45	31 55	,,	45	31 50
,,	60	31 32	,,	30	32 15
,,	75	31 6	,,	15	32 32
			The sun setting ...	0	32 51

If it is maintained that the orbit is an ellipse, because the sun appears larger at a lower altitude in December than in June at a higher elevation; on equally good data we may state that its diurnal path is an ellipse, and that our approach to the sun morning and evening is compensated by the obliquity of the rays and greater velocity, thus forgetting the consequence of such deductions at those places under the sun in the opposite hemisphere. When Kepler established the eccentricity of the earth's orbit little was known of refraction.

by a grain of sand less than one-twentieth of an inch in thickness."

Let us consider what would be the nature of the deposition in a large tract of land like Australia, gradually propelled by the permeating forces from its present position to the north polar region. Here and near it, tree ferns, Cycadeæ, Araucariæ, Cassiarinæ grow upon the land: corals and sponges abound on the coast even of Van Diemen's Land; also Trigonia, Cerithium, Isocardia, a Cardium like *C. hillarium* of the greensand, and quadrupeds of the peculiar marsupial races, to which the Stonesfield animal is referred by Cuvier. These would be deposited in the depressions, and their place would become by degrees occupied by others as it approached the equator, where it would be inhabited by a different variety. These would again retrograde southward and disappear on the arrival of the land in the north, and their place would be taken by others from more northern zones. The contents of the deposition, supposing the land undulated, as it does at present, above and below the level of the sea during its movement from the south to the north, would represent the order of deposition and organic remains in the exact order they are now found in the rocks of the northern hemisphere, viz. the first sediment enclosing the remains of the southern zone; the second the tropics, and the third the northern hemisphere.

CHAPTER XXII.

ON THE POSITIONS, UNDULATIONS, CONTORTIONS AND FRACTURES OF THE SEDIMENTARY ROCKS.

THAT subterranean forces have acted on the sedimentary rocks during and after their formation, is abundantly proved by their general appearance in all parts of the world. We have shown that the surface of the crystalline rocks and the beds deposited on them have been cleaved, fractured and dislocated, and that there is scarcely an area of a few square miles which does not bear marks of having been disturbed and altered by chemical forces. Since this is the case, it is reasonable to suppose that the sedimentary beds must be subjected to many changes by the constant but insensible slow action of the polar crystalline forces. This power being perpetual, alters the plane of the beds by numerous undulations and different relative positions during their depositions; so that a series may commence to be deposited on a concave, half formed on a level plane, and completed on a convex surface; sometimes receiving the elements on the one side, and again on the other, according to the nature, amount and continuity of the undulations.

Suppose, for instance, we examine a series of rocks in the northern hemisphere, and find them to contain in the ascending order, first, beds with organic remains belonging to the south temperate zone; another series of beds inclosing marine and terrestrial animals corresponding to those of the tropics resting on them; and again, beds of marine and freshwater shells alternating, similar to those now living in the northern hemisphere, completing the series: it would be very evident that such a deposition must not alone have taken place during different periods, but likewise in different climates, and consequently such a formation would show that the beds must have undergone a considerable oscillation since the commencement of their deposition. The series, in moving from zone to zone, would be governed by the local nature of the base on which it rested, and would necessarily conform to all the changes which may periodically occur in the inferior bed. One of the most satisfactory results arrived

at in the study of the sedimentary rocks, is the certainty that the subterranean movements were not all of the same date, and that some rocks had been bent and disturbed before others were formed.

Let us suppose a coal formation to be now forming near the mouth of the Rio de la Plata, and the movement *en masse* northward to be 20 seconds per annum, it would take 2200 years to arrive within the tropic of Capricorn; during this period there would be very considerable changes in the configuration of the land; and when we consider the longitudinal extent of the movement, say about 750 miles, we need not be surprised that the mass should happen in the interim to be much contorted and elevated or depressed a few thousand feet from its former relative position. From the tropic of Capricorn to the equator the sedimentary mass may remain above the level of the sea and form the habitation of the organic beings confined to that part of the earth, whilst another mass of the same age may still remain under water. From the equator to the tropic of Cancer it may become again submerged below the level of the sea, and thus receive additional layers of sedimentary beds; on its emergence from the sea in the northern hemisphere, it would present an undulated compound, containing a different series of organic remains belonging to distinct zones, with one strong line of demarcation, showing the absence of the beds belonging to the south tropical zone, arising from its being then above the sea level. It will, therefore, be observed, that although the sedimentary series of rocks are commonly described as if they were regularly built on each other in the following order, Cambrian, Silurian, Coal formation, Lias, Oolite and Chalk, with a series of beds called Tertiary, they are never found so complete in nature. It is true that the order of the beds is never found inverted, yet a great number are always absent, and their respective developments vary considerably in different localities. England contains almost all the series from the south frigid to the north temperate, not piled on one another, as described in the usual geological sections, but overlapping at the edges at different extremities of each other, thus showing that although some parts were constantly under the sea receiving new deposits, they were not always the same, but alternately changing accord-

ing to circumstances. In reading some geological works it may be supposed that the earth was once actually covered by all the variety of beds, like the concentric coats of an onion; but such an idea is very erroneous; it is abundantly evident that many of the deposits were local.

In order to give a more general idea, and comprehend the relations of superposition of the sedimentary rocks, as actually observed in the different zones from south to north, and to show that although the order is never inverted, the beds are often wanting, and seldom seen in their complete numerical order, we shall enumerate the series in the following manner:—

Deposits.	Contents.	Geological names.
1. South frigid zone.	Trilobite, Orthoceratite, &c.	Cambrian and Silurian.
2. South temperate.	Terebratula, Producta, Encrinite, Spirifera, &c.	The great coal formation.
3. South tropic.	Ammonites, Belemnite, Gryphite, &c.	Oolite.
4. North tropic.	Echinus, Fusus, Pecten, &c.	Chalk and clay.

1. Commencing our examination south in Patagonia, we find, by a transverse section from Rio Santa Cruz to the base of the Cordilleras, and another on the Rio Negro, that the whole sedimentary series is of recent origin, and irregularly covering the primary rocks. The shells and corals of the lowest deposit are those which belong to the bordering sea. Scattered over the whole, and at various heights above the sea, from 1300 feet downwards, are recent shells of *littoral* species of the neighbouring coast, so that every part of the surface seems once to have been a shore, thus indicating a very gradual elevation. In this part of the globe we only find irregular recent beds of No. 1. The fossils of Tierra del Fuego and Falkland islands can hardly be distinguished from many of the species found in the Silurian rocks of England.

2. *The south temperate.*—In the Brazils we find isolated masses of No. 1, with occasionally thin beds of No. 2. In Australia, on the eastern coast, a similar series has been observed.

3. Near the equator, according to the section, Plate VII., embracing the three Cordilleras, the following numbers will represent the variation in the ascending order of the sedimentary beds:—

Sedimentary . .	3			3	3			3		
	1	2	1	2	1	3		1	3	
Primary	0	0	0	0	0	0	0	0	0	0

This enumeration furnishes an easy method of indicating the equivalent beds, apart from their relative ages in the different zones, and also the local suppression of some of the series.

4. *North tropic.*—The sedimentary rocks of this zone are similar to the preceding, but much more developed. In the north temperate zone these rocks have been well investigated; and we find in the United States and Europe the following order:—

	3	4								4		
Sedimentary .	2	3	4	3			2	4	4	2	3	
	1	1	2	1	4	3	1	2	3	1	1	
Primary	0	0	0	0	0	0	0	0	0	0	0	0

Consequently it follows, that although No. 4 (chalk) covers No. 3 (oolite), the latter is not always formed: either of the series may be deposited immediately on the primary base; and it is necessary to obtain other indications than No. 3 to ascertain the existence of No. 2 under it. However, we know that No. 3 cannot be found under No. 2, nor any other in the inverted order. A deposit may be of the same age and belonging to the same zone, that is, exactly equivalent to another, and yet differ both in lithological and zoological character, and thus cannot be determined without the aid of the inferior and superior beds.

In Ireland, I remember seeing pits being sunk in No. 1 in search of No. 2 (coal) on the eastern side of the Wicklow mountains; although no fossil could be detected in No. 1 to prove that the coal beds could not exist below, yet the structure of the rocks, and their lamination, enclosing veins of quartz and pyrites, were sufficient to show, not only their contact with the primary base, but their actual transition: it was like cutting into the body of a tree in search of the bark. When the upper series of the sedimentary beds are much developed the lower are

seldom found underneath, and *vice versâ*. It is essential to bear this fact in mind when making trials for coal below the Chalk, Oolite, &c., as a thick seam of coal could not exist, even had it been originally deposited in the spot, under such a pressure as would be produced by a *complete set* of the European superincumbent series; therefore those who have studied geology from theoretical sections must modify their ideas on this point, and study Nature.

Some geologists have actually attempted to calculate the thickness of the sedimentary series by means of the angle of the planes of cleavage. To deduce the thickness of the earth's crust by the planes of lamination, is like calculating the depth of a transverse section of a tree by the *medullary rays* instead of the *concentric rings*; and must have proceeded from confounding planes of cleavage with planes of bedding.

The more recent deposits must necessarily be less contorted and fractured as a whole than those which are more ancient, on account of their being subject to less disturbances, and not so compact: the fractures and dislocations visible on the surface of any series of rocks would not therefore afford a just estimate of the amount of disturbances to which that particular part of the earth's surface has been subjected. Extensive ranges of country often have the beds of rock of which they are composed thrown into particular lines of direction. Such lines, when considered in the usual manner with reference to our general ideas of distance, appear of considerable length; but when viewed, as they should be, in connexion with the whole superficies of our spheroid, a large proportion of them lose their apparent importance: many of them are then seen to be so short, that the cracks or elevations of strata by which they are marked may readily be conceived to have been effected by comparatively small intensities of force. It is a want of due attention to the relative proportions of the radius of the earth to the height of mountains and the undulations of strata, which is the cause of such disturbances being considered as the result of tremendous igneous forces. Most gigantic and awful igneous eruptions are commonly brought forward to account for disturbances which could be effected by an ordinary hydrostatic press connected with a subterranean sheet of water.

It is a singular fact that the sedimentary beds are principally tilted on the *southern edges* in Europe and America, indicating very forcibly the effects of a northerly action. And we find also that the ridges are principally on the western sides of the continents and islands, and the sedimentary plains on the east flanks.

Movements, fractures and dislocations, of such order, regularity and extent as we find in the whole masses of rocks constituting the surface of the globe, require a corresponding, slow, regular and powerful acting cause, such as that which we find in the operations of terrestrial magnetism. Volcanoes and earthquakes are merely secondary forces, *i. e.* the effects of the subterranean currents; therefore even the local and irregular disturbances from these must be classed under the same natural operation as those above alluded to. It is anything but desirable to have constant recourse to great forces in explaining geological phænomena, when the exertion of a comparatively feeble power will afford sufficient explanation. In coal works, when the workings happen to be very extensive, the lower beds are often seen swelling upwards, and sometimes the upper bulging downwards until they meet, without producing a single crack: here we have contortions of solid rocks by a slow action, without those awful subterranean convulsions and igneous matter to soften rocks, which some are so fond of contemplating. The mere elevation and contortion of mountain masses can be produced by a slow force as well as by other means; and the examination of these upraised mountains shows that the effects could not be produced by one great and instantaneous action. Contortion requires that the rocks should be in a yielding state, and that the particles be capable of a certain movement among each other, so that in applying force no absolute fracture would occur. Were we to attempt to bend a bed of limestone by one instantaneous action, it would immediately break; but if we gradually apply pressure, so slow as to afford time for the constituent particles to adapt themselves to the change, the bed may be subjected to any degree of contortion without fractures while *in situ*. The volcanic forces are insignificant compared with the apparent feeble force of crystallization; it is like the effect of a blow from a sledge on a sheet of ice on a pond, compared with those effects which would be produced by water if confined and

connected with an hydrostatic press; the former would exhibit a great break in one individual spot, but the latter would fracture and bend the ice throughout by a slow and insensible action. The disturbances thus produced on the ice would be greater than those observed in the crust of the earth, when viewed in their relative proportions.

When we consider that rocks have been liable to be contorted from the time they were in a state of mud to their consolidation, we can easily conceive why they should present such bends as we now find in them. The extent to which the particles of various rocks, saturated with water as they always are in nature, may be compelled to move among each other by great pressure, has never been sufficiently considered. Indeed rocks have been viewed too much in the sense of dry, hard and inert, instead of active and moist masses: an absolute dry and compact rock would be a phænomenon in nature, *i. e.* an extraordinary exception to the usual natural production.

It is exceedingly difficult to expel moisture from rocks, and when expelled the difference in weight is found very considerable. Limestones contain a great quantity of water, and are sometimes found at great depths very soft; and often, by means of the weight of the superincumbent beds, they force a great proportion of their soft parts into the joints of the bounding rocks. Sometimes limestone beds and hornblende veins have been thus introduced between the planes of sedimentary beds. As this part of the subject has been anticipated by the observations made on the nature of the crystalline rocks, we need not extend them here; we shall conclude by stating that stratified rocks are not homogeneous inflexible dry and solid masses; on the contrary, they are composed of numerous moist and pliable sheets, capable of extension and compression, easily twisted and bent under pressure, the productions of different zones, and are constantly propelled forward towards the north pole.

CHAPTER XXIII.

ON THE ORGANIC PRODUCTIONS OF THE DIFFERENT ZONES.

THOSE who have the opportunity and capacity of surveying nature with a comprehensive glance, and abstract their attention from local phænomena, cannot fail to observe the great difference which exists in the organic development of the zones of the southern hemisphere as compared with those of the north. According to the ordinary notions, the variations in the degrees of vitality are solely governed from the equator towards the poles by the decreasing strength of the animating heat of the sun, and consequently, the productions of corresponding latitudes, on either side of the equator, are more or less alike; but this is far from being the case.

In order to show the peculiar characteristic difference, we shall give a short description of each zone, so that the reader may be more able to appreciate the cause of so great a difference in the character of the organic remains which we find in the old sedimentary series, and those now existing in the northern hemisphere.

Antarctic region.—Leafless Cryptogamia (fungi, lichens, &c.) are nearly the only species found even on the external margin of this region. This paucity of vegetable species corresponds with the paucity of animal forms. Even in Deception Island (lat. 62° 50′ south) only lichens are met with and no grass, and further south terrestrial Cryptogamia are wanting. Antarctic phanerogamic vegetation is also poorer in species at equal distances from the pole as compared with the north; yet, as we pass to the next zone, the vegetable kingdom becomes at once luxuriant in magnitude, although somewhat meagre in variety; consequently totally different to that gradual transition we observe in the north from the temperate to the arctic zone.

In Sandwich land, 59° south lat., perpetual snow and ice reach to the sea beach; and even in the island of Georgia, 54° south lat., the line of perpetual snow descends to the level of the ocean; and ice has been seen floating towards the equator to the latitudes of 36° and 39° south.

The islands and new continents now gradually emerging in this region are mere barren wastes covered with sea sands, the dung of aquatic birds and shells being scattered over the whole at various heights above the sea, with recent shells of littoral species of the immediate coast, having no traces of terrestrial animals, and entirely different to the old arctic lands with their various beds of organic remains. The next zone presents almost at once a tropical aspect as regards plants, and of the maximum dimensions.

South temperate.—Some of the noblest forms of vegetation are found in this zone, such as the tree-ferns and palms, and advance south to the parallel of 53°: these are scarcely seen beyond the tropic of Cancer in the northern hemisphere. Tree-ferns thrive admirably well at Hobart Town in Van Diemen's Land; also in New Zealand and Campbell Islands. Even in the Archipelago of Tierra del Fuego south, corresponding to the latitude of Liverpool north, vegetation thrives most luxuriantly in large woody-stemmed trees of fuchsia and veronica. That this difference is owing to the influence of the zone, and not the species, is proved by the fact, that plants which are in England annuals, become, when transplanted there, perennials. This has been observed to be the case even with barley, beans, &c. The wheat grows exceedingly high, the stalk being so strong that it has the power of resisting the winds. The myrtle, fuchsia and ferns are timber trees to the lat. of 50° south, and the humming-birds are common in the forest.

South America appears to be the most beautiful portion of the palm world, in consequence of its being situate within the limits of the south temperate zone and connected with the tropics. Coniferæ, palms, &c., still grow together in this region in gigantic dimensions and in profusion, and also in New Zealand and Patagonia; and the marshes are equally luxuriant in succulent plants.

Among the tallest of living trees the Norfolk Island pine is found in south latitude 30°, and not even known in the northern hemisphere. The abundance of moisture and equalization of heat, so peculiar to this division of the globe, stimulate the vital powers of the vegetable world; and again, the nutritious plants,

together with the climate, appear to act with equal power in augmenting the size of the herbivorous animals.

In ascending from the vegetable to the animal world, and from one rank of animal existence to another, the most admirable order is manifest. We behold in every region striking instances of the structure of animals being fitted to the productions of the different zones. Limited as this zone is in dry land at the present period of the world, there yet exists the representatives of the former bulky herbivore in the forests, and the remains of the sloths, armadillos, opossums, &c., are frequently found mixed with those of the Megatherium and Glyptodon in Patagonia.

The amphibious reptiles and sauroid fish become also conspicuous as we proceed towards the tropic of Capricorn, both on the coasts of America and Australia; thus presenting an organic aspect totally different to the north temperate.

The degree of development attainable by organic forms, vegetable and animal, is determined by laws which have not been sufficiently studied. We find in each of the divisions of animated nature a gradual diminution in size from the south temperate to the arctic region; the colossal reptiles, saurians, &c. of the south dwindle into mere small lizards as we recede northward; and even man oscillates from a Patagonian or Amazonian giant to an Esquimaux; and such is the case with a very large proportion of the organic kingdom.

Tropical zone.—In roving through the forests in the lowlands of South America, especially between the rivers Orinoco and the Amazon, the earth is so overloaded with thick and gigantic vegetation as to render it impenetrable for beasts. In these regions we consider man as a being not congenial to that order of nature. The earth luxuriates in its gigantic and thick development of plants, and solemn silence prevails, excepting on the banks of the rivers. The crocodile, sharks, boas, &c. are masters of the rivers; the jaquar, pecari, tapir, &c. rove along the banks, and the serpents occupy the high grass; nothing impeding their increase, residing there as in an ancient heritage or primæval world, without fear and without danger. Human beings and domesticated animals are looked at in such

a scene as inhabitants of another world. Were this region to sink 320 feet, the whole surface would be covered by the Atlantic Ocean, and the eastern declivity would become again, what it was before, a shore of the ocean. The great oscillations of these countries tend to destroy the larger animals in consequence of altering the physical conditions; hence the larger type becomes gradually lost in the course of ages, while the lesser remains. The Megatherioids of South America have disappeared, but the Sloths have remained, and many races of animals have not only lost the larger types, but deteriorated from the same physical changes. The comparatively diminutive animals of South America, Australia and New Zealand, which are the allies of the gigantic extinct species, have been preserved, like descendants of former races, owing to their being more capable of existing under less favourable physical conditions than the larger animals. The proportion of land now occupying the south tropic and south temperate is far too small to supply the necessities of the larger tribe. It is very probable that Australia was not connected with a tropical continent previous to its emergence; hence the cause of the great deficiency in quadrupeds. The small animals belonging to this region have evidently come from islands, and have accommodated themselves to the narrow limits produced by the changes under which the larger species must have succumbed.

Notwithstanding the power and richness of the vegetable productions within this zone, we often find vast arid tracts surrounded by borders of evergreens—seas of sand, as it were, where no animal could exist; with here and there only a few isolated fan-palms. These great plantless tracts of land, in regions characterized on every side by the most exuberant vegetation, is a geological phænomenon not properly attended to. Humboldt very justly observes, that when once a region loses its vegetable mould, and becomes covered with a thick layer of sand and gravel, many centuries may elapse before the surrounding greens will cover the dreary waste; hence the larger herbivorous animals, under such conditions, will perish for the want of food, and the carnivorous will also have to migrate and perhaps suffer in a less congenial habitat: all become subservient to the various effects of geological mutations.

North temperate.—The tree-ferns and palms scarcely extend in a diminutive form to this zone. The small grass, fine mea-

dows, and the periodical renovation of nature at the first genial opening of spring, become in this division of the earth more conspicuous than in any other. Although the gigantic forms do not flourish so far north, yet this part of the globe is more prolific in the variety of the lesser vegetable and animal productions. Some suppose that the long-haired elephantine animals, which are found imbedded in the northern sands, were once indigenous to this zone, and that animals of similar forms, belonging to the same type, were capable of living in the northern climates,—productions which are totally inconsistent to the physical conditions. Even were we to admit such a mode of reasoning, it could not be extended to vegetation, which requires moisture and tropical climate. No internal heat, in the absence of suitable external conditions, can produce gigantic plants with their delicate appendicular organs; therefore, as the one accompanies the other, the same mode of explanation is essential, and must be applied to both forms. We know from ample experience in hot-houses, that internal heat, in the absence of light and mild moist air, would be destructive to the glossy verdure of the vegetable kingdom. The heat of the volcanoes of Iceland would be of no avail to vegetable life in that latitude.

I have no doubt but that many parts of the lands of the northern hemisphere contain seeds of vegetable forms which cannot germinate for the want of the conditions the southern hemisphere still presents. To show that such instances occur, we need but refer to the fact, that in destroying large forests in South America, we frequently cause the growth of plants unknown to the inhabitants of the locality. Hence seeds may remain dormant or rendered as inactive as those found enclosed in the Egyptian mummies even in their congenial habitat, owing to the predominating powers of their more vigorous companions. In transplanting the northern plants to the south, they increase in magnitude, while those brought from the south to the north become dwarfish, and only the more hardy variety and the small species can conform to the transition.

The northern temperate zone is divided by the ocean into two great continents. The same tribes are found to be spread from the western to the eastern parts of the old continent; but the quadrupeds which inhabit the temperate climate of America are peculiar races analogous to its corresponding southern part;

whereas the former, owing to the sudden break from the tropics by means of the Mediterranean sea, presents a great range in the same parallels. In the arctic region, we find the White Bear, the Reindeer, Foxwolf, &c.

In proceeding from the torrid zone towards the arctic region, the animals become smaller, less numerous, and less ferocious. The reptiles and serpents gradually diminish in number and venom as we go north, until they disappear entirely in the frozen region. The smaller grass, grain and other nourishing farinaceous productions of this zone, although not sufficiently succulent to suit the larger animals of the preceding division, are favourable to the Horse, Ox, and other domesticated animals, and consequently these come to their perfection in this division. In the northern part of this zone the vegetation is very scanty, principally dwarfish oak trees, pines, and some evergreens; but the pasture is rich; rye, oats and barley can be cultivated almost to the boundary of the arctic region.

Before we close this chapter I shall make a few observations on the supposed predominance of carbonic acid in the atmosphere during the deposition of the coal-beds, inasmuch as the question has reference to the physiology of vegetation. The researches of M. A. Brongniart on fossil plants led him to conclude that during the early period, when the succulent plants entombed in the coal-measures flourished, the atmosphere was more charged with carbonic acid than at present, aiding, it is said, the development of the gigantic species seen in the coal; which were similar to those now living in the southern hemisphere. It is difficult to conceive how the idea of plants obtaining their carbon from the atmosphere originated, when it is a well-known fact to those who study nature, that the plants are fed from the *soil* by means of the absorbing power of the roots. The carbonaceous liquid enters the roots by their extremity, passes into the cellules, and reaches the stem, where the ascending movement is continued; it precipitates some portions of the component compound in its course, increases in density, and constitutes then what is called sap; and it feeds the woody fibre and the bark by means of the medullary rays.

The intensity of the ascent of the sap depends on the power

of the bark, in the radial action, and the buds and the superficial area of the leaves in evolving the gases from the extremity of the pores of the fibres. The evaporation of the gases at the leaves keeps the ascending movement from cell to cell in activity, and this brings up the nourishment necessary for the development of the trunk. Those who have lived, like myself, for many years in the midst of such gigantic vegetation as above alluded to, are fully aware that the atmosphere (with the exception of being occasionally overcharged with moisture) is as pure as it is in the northern hemisphere.

The aborigines of New Zealand, Australia and South America, however ignorant they may appear to the world, would smile at the notions of our philosophers regarding the physiology of vegetation, and many other natural phænomena with which Europeans are not sufficiently acquainted. The evolution of the gases at the leaves has been found to vitiate the atmosphere, more especially at night, when the air is stagnant; the sun's rays appear to restore the purity of the air. I found by experiment that the elongation of the plants was greater by night than by day.

The soils of these regions are strongly saturated with carbonaceous matter, both elementary, and as deposits of pre-existing carbonaceous compounds; consequently with such an abundance of nourishment to feed upon, and *constant mild and moist* atmosphere to keep the leaves in a healthy active state to liberate the gases, the plants must flourish.

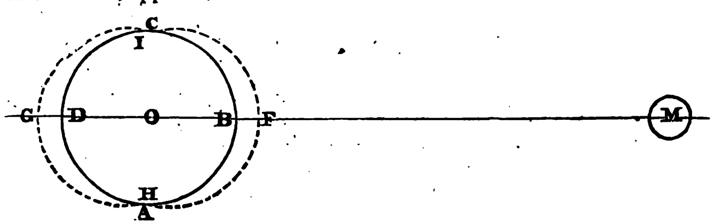
The function of the leaves is to evolve the gases, *i. e.* they form the negative plates as it were to the currents of sap in the vegetable battery. Had there not been a provision in nature to throw down the carbonic acid gas which occasionally contaminates the atmosphere, we could not exist; nor would vegetation thrive, as proved by experiments. Carbonic acid atmosphere, even to a moderate degree, is destructive to vegetable life; whereas, if absorbed by the soil, it becomes highly nutritious. Yet, although these facts are so easily proved, and well known to the cultivators of lands, we find the assumptions of carbonic atmosphere, and feeding by means of the leaves, encouraged by eminent scientific men.

CHAPTER XXIV.

ON THE APPARENT INFLUENCE OF THE MOON ON THE SURFACE OF THE EARTH, AS EVINCED BY THE ACTION OF THE TIDES AND THE SAP IN TREES, ETC.

THIS subject is not only very little understood in Europe, but almost neglected; with the exception of the movements of the tides, in which the moon is considered to be the prime mover, and made to act in a strange manner on the ocean (usually styled the theory of the tides), we have no other *acknowledged* records of her terrestrial operations amongst scientific men*. The abo-

* It is said "that when any part of the surface of the sea is turned towards the moon the water is drawn towards it, and raised into a tide, which falls again when the place is turned away from the moon. The water rises to the same extent on the side opposite the moon; so that there is always high water on the two opposite sides of the globe at the same time. Let A B C D represent the earth, and M the moon, and let the surface at B next the moon, and that at D, opposite, consist of water." It is said, "as the force of attrac-



tion is greater in proportion to nearness, and less in proportion to distance, the moon will exert her greatest influence on the waters at B, which accordingly will be drawn towards the moon to F, and their surface will form the dotted curve. The waters on the opposite side being further from the moon than the earth, the moon will attract the latter more strongly than the waters. The earth, therefore, will be drawn away from these waters; and they *being left at a distance* somewhat greater than the usual surface, will appear to have risen from D to G." If the moon be capable of attracting the water at B, and the *whole bulk of the globe besides,* what keeps the water up at G? Surely the little covering at D would follow, if not withheld by some external power not noticed in the demonstration, and especially when the sun and moon are in conjunction. It may be argued that Laplace and other astronomers have

rigines of the torrid zone and southern hemisphere, where meteorological phænomena follow each other with great order and regularity, watch them with great attention, and their prognostics from the appearance of the moon are as much to be depended upon, or even more so, than the barometer in Europe.

Our knowledge of the general movement of the tides is so incomplete, that many believe that they are great meridional ridges, following the apparent movement of the moon, and not —as we observe them—waves propagated from the south. However, our object at present is not to enter into this question, but to show that there is an apparent physical connection between the moisture enveloping our globe and the moon. The tides move northerly in waves, and vary in their dimensions in both oceans with the changes of the moon: this is known from time immemorial; therefore we need not dwell on this effect, but proceed to the oscillations observed in the vegetable kingdom.

In carefully studying the action of the sap, more especially in the south temperate and torrid zone, we find that there is an intense ascending movement from the new moon to the full, and a repose during the decline. Indeed so regular and well-known is this fact amongst the natives of the hot countries, that it becomes a most important guide in cutting timber. They know from experience that if trees,—palms, bamboo, &c.,—be cut during the increase of the moon, they become rotten in a very short time, whereas if cut during the decline they are firm and permanent. I have made practical experiments for upwards of nine years, and have proved the above to be a fact, and if the rule for cutting be neglected no woodwork of any permanent value could be made. So strongly saturated are the trees during these periods,

established the consistency of such a doctrine: but as all the complicated and intricate analysis used rests on the truth of the conjectures or assumptions made for procuring the possible application of the fundamental equations, the argument is of little avail. Had such tides existed at the equator, proportionably to the supposed attractive curve, in the ratio of the length of the ordinates, according to the geometrical degrees of intensity, the Low Countries would be completely inundated; but the fact is, there are *no such tides at the equator*, in the Atlantic, nor in the Pacific. The tides bordering the Pacific islands and in the West Indies are comparatively insignificant, amounting only to a few feet, and the movements of which are totally different to that indicated by the above theory, as already explained, and well known to mariners.

throughout the year, that if cut down they become immediately affected by the dry rot. During the latter period of the change, the gases evolved from the leaves and the woody substance become consolidated, and they are rendered fit for cutting. The rings of the trunks are formed monthly in the southern hemisphere, by the expansion of the outer part during each period of activity: hence a tree of twenty years frequently contains 260 rings called 'annual rings' by Europeans, the fossils of which lead to erroneous computations.

In crossing the Andes, we find it much more convenient to travel through places where there is a deficiency of water, during the increase of the moon than the decrease, inasmuch as we are able to obtain pure water by tapping the trees in the former case, but not on the decline. The action of the sap accompanying the changes of the moon is equally conspicuous in the operation of cutting and grafting, which if not attended to will endanger the life of the plants. Nor is this apparent influence of the moon confined to the southern hemisphere and torrid zone, but also extends northward. They know in the United States that it is essential to the durability of timber to cut it at the period of the 'dark moon.'

This fact has been found of sufficient importance in the United States to cause the government to establish the following law; viz. the timber supplied for the navy ships of war is required to be girdled, or felled at the *dark moon*, between the 20th of October and 12th of February. White pine logs, if stripped of their bark and cut at the proper period, *i. e.* during the decline of the moon, will remain uninjured thirty years; whereas if cut at the increase of the moon, they will be either attacked by worms, or destroyed by dry rot in a very short time. These effects are much more conspicuous in the south than they are in the north, but nevertheless they are of great practical importance in all countries where timber is required.

It is interesting to study these also in the animal kingdom: they are as striking and unequivocal as in the former; and are sufficient to prove the connection that exists between the surface and the moon, although the mode of operating is very different to that explained in our old theoretical works.

CHAPTER XXV.

ON THE GENERAL NATURE OF THE DISTRIBUTION OF HEAT OVER THE SURFACE OF THE GLOBE, AND THE ZONES OF EQUAL TEMPERATURE.

It is now well ascertained that zones of equal warmth, both in the atmosphere and in the waters of the ocean, are neither parallel to the equator nor to each other. It is also known that the *mean* annual temperature may be the same in two places which enjoy very different climates; for the seasons may be nearly uniform or violently contrasted, so that the lines of equal winter temperature do not coincide with those of equal annual heat. The deviations of all these lines from the same parallel of latitude are determined by the position, direction and elevation of the continents and islands, the position and depths of the sea, and the direction of currents and of winds.

The amount of the solar heat depends upon the position of the sun, the direction in which the sun's rays strike the earth, and the variable degrees of intensity occasioned by the atmospheric lens, illustrated in Plate III. In proceeding from the equator towards either of the poles, without altering our height above the level of the sea, we must travel a great distance before we find the mean annual temperature reduced even a few degrees; but by increasing our elevation, a rapid change of temperature will be experienced, till we arrive at the point where constant frost prevails, *i. e.* the curve of congelation. (See Plate III.) The annexed table shows the relative height of this curve in different latitudes from the level of the sea:—

Latitude.	Height of Curve of Congelation.	Mean temperature at the level of the sea.
0	16,000	84·2 Fahr.
10	15,600	82·6
20	14,500	78·1
30	12,600	71·1
40	10,000	62·6
50	6,900	53·6
60	3,900	45·0
70	1,000	38·1
80	0	32·0

The variable temperature of the sub-aërial zones in the ascending order is also observed in the sub-aqueous zones from the level of the sea downwards. At the equator, commencing from the level of the sea upwards, we have the following:—

	Mean temperature.					
Level of the sea	84°.					
4,000 feet high	70°,	descending to the level of the sea in				30° N. lat.
8,000 „	62	„	„	„	„	40
12,000 „	44	„	„	„	„	60
16,000 „	32	„	„	„	„	80

These curves descend more rapidly in the south than they do in the north.

From the level of the sea downwards the temperature decreases in the torrid zone from 82° to 39°: the sub-aqueous zones are not so uniform as the aërial, and are considerably influenced by the polar stream.

According to the concentrated rays, the heat of the sun ought to increase in depth, and such would be the case in an empty space; but liquids conduct heat very imperfectly downwards. A thermometer let down a few feet below the surface of a pond or of the sea, would, on being drawn up, indicate a lower temperature than that of the surface; for the latter, heated by the rays of the sun, would communicate by conduction little or no heat below. It can be proved by experiment, that water does not transmit heat downwards by conduction; whereas, in applying heat underneath it is easily transmitted. Had the globe contained an igneous nucleus, whatever might be the bad conducting quality of the crystalline shell, it would be heated, and that heat would be communicated to the ocean, and an ebullition would be produced sufficiently strong, if not to cause evaporation of the ocean, at least to prevent the formation of ice at the poles, and the heat would increase as we descended. The observed facts are quite the reverse. The ocean at a certain depth possesses a constant temperature of about 39° below the influence of the heat of the tropics or the cold of the north; it is at the surface the greatest variations of temperature take place, and from which they diminish as we ascend into the air or descend into the ocean, till in each direction they terminate at

an invariable temperature, where the solar radiant heat becomes insensible; and it is within these zones of variable temperature that the animal and vegetable kingdoms are bounded.

According to the above, we find that in sailing from the south pole to the north we are exposed to zones of variable temperature, commencing at 32° Fahr.; and on arriving at the equator, it amounts to 84°·2, and becomes reduced again as we approach the north pole to 32°. If, instead of sailing on the ocean, we sail through the air at the elevation of the above curve, we should be constantly exposed to the low temperature of 32°. The variable height of the land between the level of the sea and the curve of congelation must therefore vary the climate of the different zones, independent of their latitudes. Within the tropics we may obtain any temperature from 84°·2 to 32°, by regulating our elevation; but in the frigid zone we are limited for the want of direct rays, and cannot obtain a mean temperature above 50° by depression, or by any other means we may choose to adopt; consequently no changes in the relative position of land and sea can produce a tropical climate in the polar zone. Countries in the northern hemisphere are rendered warmer by having large tracts of low land to the south and sea to the north, and cooler when the relative positions of these two are reversed. This fact is exemplified by a comparison of the climate of Europe with that of America and Asia. The western parts of the old continent derive considerable warmth from the low sandy region of Africa and the Gulf-stream. On the contrary, the north-eastern extremity of Asia and the west coast of North America experience in the same latitude extreme cold; for they have land on the north between the sixtieth and seventieth parallel, and to the south the Pacific Ocean. The whole of Europe, compared with the eastern parts of America and Asia, has a much warmer climate than is due to it according to its geographical position. If lines be drawn round the globe through all those places which have the same winter temperature, they are found to deviate from the terrestrial parallels much more than the lines of equal mean temperature. All these important considerations must be well borne in mind when we enter into the boundaries of the respective zones.

Having thus noticed the subject of temperature, it will be

proper to advert to the amount of moisture which the atmosphere contains in different parts of the globe. We have already alluded to the character of the southern regions, and that the evolution of hydrogen was probably the cause of the excessive moist atmosphere and the mildness of the climate. In the temperate zone of the north, with a mean temperature of $52\frac{1}{4}°$, the annual evaporation has been found to be between thirty-six and thirty-seven inches. At Cumana, on the coast of South America (north lat. $10\frac{1}{2}°$), with a mean temperature of 81·86 degrees, it is more than 100 inches in the course of the year; at Guadaloupe, in the West Indies, it has been observed to amount to ninety-seven inches. The average yearly quantity of rain is greatest within the tropics, and it seems to diminish the further we recede northward from the equator. In general much more rain falls in mountainous countries covered with extensive forests than in those where wood is less abundant, owing probably to the excessive evolution of hydrogen. The following table shows the quantity of rain fallen at Marmato, on the western Cordillera, latitude 6° 28′ north, elevation above the level of the sea 4836 feet, mean temperature about 68°, from the year 1833 to 1841 inclusive, registered principally by the author.

	1833.	1834.	1835.	1836.	1837.
	Ins.	Ins.	Ins.	Ins.	Ins.
Jan. to March..	15·15	5·15	25·14	23·3	8·1
April to June..	24·3	29·6	34·6	39·4	23·9
July to Sept. ..	2·0	12·9	21·2	18·3	18·1
Oct. to Dec. ..	17·8	24·12	36·14	28·10	31·16
	59·6	72·2	127·16	99·0	81·7

	1838.	1839.	1840.	1841.
	Ins.	Ins.	Ins.	Ins.
Jan. to March..	21·10	10·16	18·3	12·3
April to June..	41·18	28·0	22·0	26·2
July to Sept. ..	19·0	23·16	9·3	16·35
Oct. to Dec. ..	31·0	31·18	14·17	32·2
	113·8	94·10	64·3	87·2

It must not, however, be imagined that the climate of all hot countries is characterized by such abundant rains; for there

are many parts which from one year to another are either almost or entirely destitute of rain. This is the case along an extent of several hundred miles on the coast of Peru; yet the atmosphere is highly charged with moisture. There are other places on the shores of that continent where but little rain falls, but where, nevertheless, vegetation is exceedingly luxuriant, owing to the humidity of the atmosphere.

In the torrid zone, generally, the temperature ranges within comparatively small limits, and the various phænomena of the atmosphere, as observed by the barometer, occur from one year to another in a regular and uniform succession unknown in Europe: the *dry* and *rainy* seasons are the divisions of the year, depending on the position of the sun and elevation of the lands.

The subject of climate is in itself highly interesting; but it becomes still more so when we extend our view, and consider its effects upon the numerous animal and vegetable tribes which are dispersed over the earth, and compare them with those of the past, which are now entombed in our rocks.

Every climate, as we pass from the plains just raised above the level of the ocean to the curve of congelation, has its peculiar vegetation. At the equator palms flourish within the zone, varying from 80° to 60° of mean annual temperature; but on ascending to the elevation of 8000 feet above the level of the sea, to a mean temperature below 60°, they almost cease to grow. On ascending above the elevation of 8000 feet at the equator, the arborescent ferns cease to grow, and in the next zone (above) the vegetable tribe of the hot region disappears, and new varieties make their appearance, such as the oak, firs, and several others common in the temperate zone of the north. Near the equator the oak grows at an elevation of 9200 feet above the level of the sea, and never descends lower than 5500 feet. It therefore follows that if the whole of the land within the tropics were to be elevated to 8000 feet, all the tropical plants would disappear, as there would be only a temperate zone within the tropics, and even the larger animals would perish for the want of the necessary food on the flanks; if, on the contrary, the land was depressed so as to be entirely below 3000 feet, or say mean temperature 75°, there would be only the productions of the hot regions, and consequently a predominance of the large class of

reptiles and other tropical animals and plants, with the bordering sea corresponding: therefore the oscillations of the land must considerably influence the width and parallelism of the organic zones. In the former there would be no tropical band on dry land, and in the latter case it would be much augmented; consequently they can never be definitely marked, or permanently preserve their parallelism.

Each description of zoophyte has its place of residence determined by the temperature and nourishment required for its support, not alone from the sea, but also from neighbouring continents. The zones of depth below the level of the sea are governed by a similar law, but inversely to that above.

If we take a general view of the zones of equal temperature, both above and below the level of the sea, and consider that each has its peculiar vegetation, and again, that each zone is furnished with different groups of animals adapted to its temperature and general production, we can easily conceive that a very slight oscillation of land and sea would cause the extinction of whole genera of animals and plants, and that those bands of variable temperature, from the equator to the poles, can never be expected to be parallel to the equator, but always to present great undulations according to the relative position and height of the dry land and the bottom of the sea. The conditions of the Pacific Ocean are also different to those of the Atlantic. Therefore, in tracing the general effects of the northerly movement of the surfaces, and comparing the effects with existing nature, we must take all the above questions on the modifying causes of temperature and variable distribution of vegetables and animals into consideration, and not be limited to the mathematical zones of geography.

CHAPTER XXVI.

THE DIVISION OF THE SURFACE OF THE GLOBE INTO ZONES OF DEPOSITION.

HAVING explained the northerly movement and the general character of the surface, we are prepared to examine the respective, deposits, and study them in their progress from the south towards the north; and distinguish their zones of deposition in the following order in accordance to the character of their contents:—

	Zones.	Deposits.
No. 1.	South frigid	The most ancient sedimentary rocks, Cambrian and Silurian.
No. 2.	South temperate . .	The Carboniferous, or the great coal formation.
No. 3.	South tropic	Oolitic or Saurian group.
No. 4.	North tropic	Cretaceous and tertiary of Europe.
No. 5.	North temperate . .	Alluvial deposits of Europe.

1. *South frigid.*

We have already shown that this region is a barren waste, consequently the deposits can only contain marine shells, and towards the outer margin some marine plants; and it is a singular fact, that the shells correspond more or less to those found in the ancient rocks. The fossils obtained by Mr. Darwin from recent formations of Tierra del Fuego and Falkland Islands, can hardly be distinguished from species found in the Silurian rocks of England.

In Victoria Land and Franklin Islands, which are now rising from the deep, preparing new continents for future generations, there are no traces of vegetation nor terrestrial animals; hence the deposits can only enclose marine relics, and those only that inhabit that region.

2. *South temperate deposits, or the Zone in which the great Carboniferons formations were deposited.*

The forms of life buried in this system of strata are exceedingly numerous and varied, and generally in an excellent state of preservation, allowing of a most strict comparison with existing types. They consist of many races of plants, abundance of Zoophyta, with multitudes of Mollusca, Crustacea and Fishes. The plants are similar to those which still flourish in the zone, such as the large group of ferns also, the Equiseta, Lycopodiaceæ, Araucaria, Cycadeæ, Coniferæ, &c. The remains of these plants are often abundant in the coal formation. The coal plants of Europe and America are for the most part identical, and all belong to the same genera. Specimens from Greenland are referrible to ferns, analogous to those of our European coal mines. The fossil plants brought from Melville Island warrant similar conclusions, that they were all deposited in the southern hemisphere. The coal formation at Bogota, which is situated within 4° north of the equator, at an elevation of about 8000 feet above the level of the sea, contains the same kind of plants—arborescent ferns, and Lycopodiaceæ of the same species as those now growing in the southern hemisphere. The living representatives of the above are still found in Australia, New Zealand, Brazils, Chili, and various islands within the south temperate zone. Not a single species of Cycadeæ is known to grow in the north temperate region; their principal localities are equinoctial America, and southward of that part,—the Cape of Good Hope, Madagascar, India, the Molucca Islands and Australia.

The enlarged size of the arborescent ferns depends not only on a warm temperature, but also on a shady and moist place. Within the tropics they are found at an elevation of about 8000 feet above the sea, near the plains of Bogota, from twenty to thirty feet high, flourishing only in shady parts of great humidity. It is in the south temperate zone of America that the ferns and palms approach to the magnitude of those found in our great coal formation. Trees still grow in this region to a very large size, and the shrubs and smaller plants become particularly luxuriant and very productive. Much alluvial matter, saturated with calcareous and siliceous solutions, is carried down the val-

leys, blended with decomposed vegetation, and forming immense deposits. Springs of bitumen are also very abundant, and forming very extensive beds.

Were persons a little more acquainted with this prolific region, and possessing more information respecting the great deposits of calcareous, siliceous, bituminous beds, &c. which are now forming in this part of the world, they would not encourage the assumptions that the contents of the deposits represented the character of the terrestrial fauna; they would learn that they are necessarily exclusively marine. The placoid fish found in this formation, which Agassiz refers to the Cestraciont sharks, are a family still existing in the Australian seas.

This zone, as already described, contains abundance and variety of the Cycadeæ, Araucariæ, &c. on land; and Terebratulæ, Trigoniæ, Cestraciont fishes are swarming in the seas that wash their shores, corresponding to the ancient lands and seas when and where our coal formations were deposited. Those who encourage the notion of successive creations from not finding the rocks containing all the variety of organic beings, and because the consolidated sediments predominate in shells, fishes, &c., would receive a useful lesson in these regions.

Australia is exceedingly deficient in Saurians and other terrestrial quadrupeds. Hence the contents of the carboniferous group, even were land animals equally susceptible of being carried and preserved in deposits, accord well with the apparent prevalence of such a state of things in the southern hemisphere during their respective depositions.

We cannot expect to find any large coal formation far south of the tropics, but mere bituminous seams mixed with sands and clay; because should there be any forming it would be below the level of the sea, and not yet sufficiently consolidated to make good compact crystalline coal. The genuine coal formation cannot make its appearance of any magnitude until we come to the margin of the south tropic. The so-called coal formation of Australia, in 33° south latitude, is enclosed in beds of conglomerate and sandstone, with subordinate beds of bituminous shale, and very different in character to the coal formation of the north.

The dry lands of the south temperate zone are necessarily void

of the sedimentary rocks. They are principally composed of the primary series, with sands and clays partially consolidated; those now emerging from the ocean in that region have not been exposed long enough to the conditions required to form the great coal formation.

Our coal-beds are as much due to the combination of carbonic acid and hydrogen forming bitumen, as they are to decomposed vegetation. We have abundant facts to prove that plants are more liable to become silicified than to be converted into coal.

There are immense accumulations of fossil trees seen in Tropical America, all of which are indigenous to that zone. It is very interesting to observe, that in all cases the change in the organic substances depends entirely on the nature of the local solutions, and the matter in which they are enclosed, and not on the nature of the trees. It does not follow that plants should be converted into coal by being entombed in sedimentary beds of clay and sand.

Should the accumulated deposits become charged with siliceous solutions, the organic remains which may be enclosed will be silicified, be they plants or animals; and if the solutions be calcareous, they will be converted into calcareous fossils; but a large proportion of the more delicate parts become destroyed and obliterated during the chemical changes. It is only where we see bituminous springs in swamps, and lagoons containing beds of decayed palms and succulent plants, that anything approaching the conditions required to produce the coal formations is observed. Massive trees are seldom found converted into coal, even when found in the coal formation; whereas we do find thin seams of crystalline coal without the least trace of decomposed plants. The seams of decomposed vegetation are extremely irregular, whereas coal seams are the most uniform seams in the series, and which could only be produced by a semifluid substance analogous in consistence to bitumen or native pitch. The impressions of plants are generally found in the shale covering the coal, as if they floated on it, and are rarely seen *in* the coal itself.

Stumps or roots are frequently found in the fireclay under the coal; and sometimes trees intersect the seams vertically from

the clay, through the coal, shale, &c., without being converted into coal, but, on the contrary, changed into indurated clay.

The compressed wood on the brown coal formation, seen in various places on the continent, is very different to the true mineral coal, and may be very properly called lignite. They are beds of wood preserved from decay, and from mineral elements, analogous to the great trunks of trees found in bogs, which, although compact and black, are far from being coal. The cause of the supposed resemblance arises from the similarity of their *composition*, both being a compound of carbon, bitumen, &c.

Thin veins of anthracite have been seen in the superficial joints of granite and porphyry; plumbago has been found in granite and schistose rocks; in fact, bitumen flows from porphyries and schistose rocks in North America. The Lake of Trinidad is formed by such springs.

The numerous small veins of coal found in limestones, sandstones, clayslates, &c. intersecting the beds like quartz veins, prove most distinctly that they were formed by carbonaceous matter in solution and crystallized during consolidation*.

3. *South Tropical Zone. The system of rocks between the carboniferous strata and the chalk, containing a large proportion of gigantic amphibious Saurians.*

The oolitic group may be considered as representing this division of the series. The remains of plants, Zoophyta, Mollusca, Articulosa, and vertebral animals belonging to the oolitic system, are very numerous. The most characteristic of the plants are the group of Cycadeæ, of which stems in the isle of Portland, and leaves and fruit in Yorkshire, show considerable analogy to

* There is a very erroneous notion prevalent respecting the diamond. It is commonly considered as mere crystallized *charcoal* or *coke*. These comparisons necessarily lead to incorrect ideas respecting the origin of this crystalline gem. It is a pure crystal derived from the original element of carbon, like all other crystals. We may as well call a crystalline phosphate of lime, bone, or carbonate of lime, shell, as to call a diamond charcoal. The diamonds are only found in the debris of the primary crystalline rocks, like garnets, and consequently formed in the primary base from the original elements, and not by means of the transformation through the medium of vegetation, as the comparison leads the masses to infer.

the existing forms of the tribe at the Cape of Good Hope, in India and Australia.

The sponges resemble those of Australia. Among the Saurians, those which frequented the water necessarily predominate in number, but the largest forms were terrestrial (Iguanodon, Megalosaurus), but apparently deposited in local inland basins under favourable conditions for their preservation. We observe that the earliest Mammalia, of which we have yet any trace, were of the marsupial division commonly seen in South America and now almost characteristic of Australia, the country where yet remain the Trigonia, Cerithium, Isocardia, Zamia, tree-fern, and other forms of life so analogous to those of the oolitic periods. During the deposition of the European formation the rivers and shores were inhabited by Saurians more or less amphibious, while the sea was full of forms of Zoophyta, Mollusca, Articulosa and Fishes.

Within the south tropical zone we have a reflected image, as it were, of the organic contents of this division of the series in the seas and lagoons of South America. Here the rivers, such as the Amazon and its shores, are watched by amphibious Saurians, the living representatives of the Megalosaurus and Iguanodon. Although the identical species have become extinct, yet the alligator, crocodile, gavial, and the bavial of South America (the latter was seen by the writer in the lagoons of equatorial America, having a head like an iguana and a body like a crocodile), are sufficient to show the correspondence of this zone to the fossils of the oolitic group. The Galapagos Islands swarm with herbivorous, marine and terrestrial reptiles, allied to the Iguanidæ, which are unknown in other zones.

When we consider the myriads of reptiles which inhabit this zone, it is not surprising that their relics should be found occasionally in sediments deposited within their own element; but it would be extraordinary indeed to find traces of man and his works in such deposits. There are regions at present in the Indian and Pacific Oceans co-extensive in area with the continents of Europe and North America, where we might dredge the bottom and draw up thousands of shells and corals without obtaining one bone of a land quadruped. The dredgings bordering our coast have only produced marine relics; no terrestrial

remains have been found; therefore were we to reason from such evidences on the probable state of organic life, we should conclude that there were no reptiles, birds or quadrupeds existing in the neighbouring land. The casualties must always be rare by which land quadrupeds are swept by rivers far out into the open sea, and still rarer the contingency of such floating bodies not being devoured by sharks or other predaceous fish. If the carcass of a terrestrial animal should escape and happen to sink where deposits were accumulating, and if the numerous causes of subsequent disintegration should not efface all traces of the body, is it not contrary to all calculation of chances that we should hit upon the exact spot? Can we expect for a moment, when we have only succeeded amidst several thousand fragments of corals and shells in finding a few bones of even aquatic or amphibious animals, that we should easily meet with land animals? Are we then warranted in supposing that man was not an inhabitant of this world during the deposition of the oolitic group, not alone in the south tropical regions, but in the northern hemisphere? In the first place, the southern hemisphere is but thinly inhabited; and if perchance a man be carried into the rivers, he would soon be devoured amongst such a profusion of carnivorous reptiles. As to the works of man within this zone, even at the present advanced state of civilization, they consist of such materials that their remains would be undistinguishable from the wrecks of the forest. Therefore we have no reason to assume that man was not an inhabitant of this world during the deposition of the series in question, and much less other terrestrial animals.

Let us take as an example the banks and lagoons of the Amazon, which are swarming with reptiles, and consider the nature of the deposits forming at the mouth of this immense river. The inhabitants of the country are principally roving Indians, living in bamboo huts; probably we should not be far wrong in stating, that for every man, there are within this region 100,000 amphibious reptiles. Again, for every man, or quadruped, which may be carried into the mud of the river and escape being devoured, there will be deposited myriads of amphibious reptiles. The large aquatic birds of South America are never found in deposits, yet we find their foot-prints on the sand-banks of the

lagoons and rivers. I have looked in vain, during my researches in South America, for terrestrial organic remains of animals in the deposits now forming, whilst the freshwater and marine relics were often very abundant.

Some of the oolitic beds of Europe seem composed of little else than the remains of shells and corals, like the deposits now forming in the Pacific. A very striking zoological feature of this formation is the immense abundance of Ammonites and Belemnites, which must have existed during the deposition of the European group, and also when the most recent equivalent of the same division was formed, as now seen near the equator*.

arrow-he

It would far exceed our limits to enter into the general comparison which might be made, even to minute details, of the living representatives and the depositions of the river Amazon, and other parts within the south tropical zone, with the fossils and deposits of the oolitic group of the northern hemisphere; and as it only forms but a mere link in the chain of argument in support of the northward movement of the surface, we must content ourselves with a general glance. As this system of deposits was formed within the south tropical zone, the corresponding sedimentary beds, already emerged at the equator, are superficial, and in a very unconsolidated state as compared with those seen in the north. The equivalent of the European oolitic group in equinoctial America, from the Amazon to the Orinoco, and on the plains and table-lands of New Grenada, is an immense mass of alternate beds of fine-grained quartzose sandstone and conglomerates, containing Ammonites, Belemnites, and a variety of other marine shells, together with species of fossil plants of the Cycadeæ, Coniferæ, &c.; and on the superficial, arenaceous and unconsolidated part of the same series are found immense bones of the Mastodon. These bones are very abundant in the province of Nieva, amongst which are the remains of the alligator, and other existing types.

In New Grenada this series of sandstone is stratified in layers more or less horizontal; a great number of the thinner and upper seams are composed of decayed leaves and impressions of

* Some of these Ammonites, which were brought from the equator and presented to the Geological Society by the Author, are figured and described in the Geological Proceedings, vol. iv. No. 101.

plants the same as those now growing on the spot. On the plains of Mariquita and Nieva are immense isolated terraces presenting beautiful sections of 2000 feet high; and also on the plains of Bogota, resting on the coal formation of that district; whilst on the west this formation rests immediately on the crystalline schists of the central Cordillera*. The elevation of this part of South America from the level of the sea (which appears to have been comparatively recent) must have been extremely uniform in this region. There are but few beds of the oolitic group sufficiently consolidated for building stones, and those that are so employed are much softer than the common freestone. Stems of succulent plants are commonly found, as black as jet, in the harder beds.

In examining recent deposits within the tropics, we often find the accumulations of only one variety of plants; and it is remarkable that some of those which are common in the neighbourhood are yet absent in the deposits. Some plants appear more susceptible to rapid decay than others; hence it follows that a series of beds may be found to contain only a particular class of plants, without a trace of many growing within the district. We note these facts in order to guard against the too hasty conclusions of supposing that the fossils always represent the general character of the whole variety of vegetation, much less the animal kingdom.

4. *North Tropical Zone.—The Cretaceous and the so-called Tertiary Deposits of the Northern Hemisphere.*

Although the English sedimentary rocks are divided into distinct groups, it is not a natural and definite subdivision, but depending entirely on local circumstances, and very far from being applicable in the same parallels, much less in more southern latitudes. A perfect transition from one formation into another is of more common occurrence in nature than distinct separation. Besides, instead of being piled on each other as represented in the common geological sections, they merely lap over at their respective margins. We have no cretaceous equivalent to the European in the equatorial zone. The remains of crocodiles have been found in the chalk of Meudon, and the

* See Section of the Andes.

exuviæ of large reptiles at Maestricht. The remains of fish are abundant.

In examining the corresponding deposits which are now forming within the tropical region, we often find a great number of beds containing only marine and freshwater organic remains, and it is but in very few instances that we can detect traces of terrestrial animals. In some parts, large deposits of carbonate of lime are seen, with scarcely any organic remains, although forming at the same time as those deposits in which they are very abundant. Those persons who confide in what are hastily called general views, and believe in the gradual change and sequence of organic life on the globe, and picture to themselves the early land and sea as tenanted only by what they find in the sedimentary deposits of a particular region, from what they consider simple forms of life to a more complicated, till man, as they say, was at last awakened to the supremacy of creation,—would receive a useful lesson on the banks of the river Magdalena and the lagoons of Santa Martha; they would soon perceive that the few fossil birds and quadrupeds of Stonesfield, and other places, are not anomalies so puzzling as they were once considered.

Although there have been actually found, not only the bones of quadrupeds, and various terrestrial animals, but also those of man, amongst the remains of the extinct animals, in caves, &c., and also in a fossil state in the calcareous deposits of Guadaloupe, yet so obstinate is the adherence to the supposed recent origin of man and the living system, as compared with the organic remains of the sedimentary rocks, that such discoveries are not considered sufficient to prove their coexistence. Various species of monkeys have been found under similar circumstances, which were at one time considered of the same recent origin: this must show the inconsistency of the hypothesis, and how untenable doctrines check the march of scientific truths.

In the red sandstone, which occupies nearly the same geological position as the cretaceous group, in Dumfriesshire in Scotland, and Massachusetts in North America, we find the impressions of the feet of birds, and the foot-marks of tortoises. On the banks of the river Magdalena, between Mompox and Morales, the writer saw impressions of foot-marks similar to those of birds of a most gigantic size,—feet measuring about fourteen inches

long and eight inches wide, having three claws, and the steps four feet; amongst which were also those of tortoises, and various other animals well known on the banks of the river. So dissimilar were the impressions to any other but birds, as not to leave a doubt at that time but that they were produced by them, and those who have seen the drawing of these trifid foot-marks came to the same conclusion.

During a subsequent visit to this region I was determined to make a further examination of these impressions, and I found that those bird-like foot-marks were produced by the Dante!—thus showing how easily we may be misled from the impressions of existing nature, much more in the imperfect impressions of the past*.

The trees in the *dirt-bed* in the neighbourhood of Weymouth stand in or rest upon the soil in which they grew; consequently their submersion beneath the water in which the Purbeck beds were formed, and which now cover them, must have been gradual and unaccompanied by a rush of waters. Such is the case in the present formation of their equivalent in the lagoons of Santa Martha, where the trees are growing in shallow water, subject to slight oscillations above and below the level of the sea. Sometimes the salt water prevails, and the sediment becomes thickly covered with marine shells: during the great floods pouring down the Magdalena, carrying with it immense forests and the debris of rocks, the lagoons become again covered with freshwater and terrestrial organic remains. Thus, by variable seasons, and by the slow oscillation of the land by subterranean forces acting for a long period, the variable sedimentary beds are formed, such as we now see them when exposed to view.

Professor E. Forbes, in his excellent observations on the Mollusca and Radiata of the Ægean Sea, states, "It was found to be a law, that the extent of the range of a species in depth is correspondent with the extent of its geographical distribution. On the other hand, species having a very limited range in depth were found to be either peculiar Mediterranean forms, or such as are extremely rare in the Ægean, but abundant in more

* I have no doubt but that the trifid impressions in the Red Sandstone of Connecticut were produced by similar animals, and not by birds, as I have carefully compared them both.

northern seas. The Testacea of the Ægean are for the most part dwarfs, as compared with their analogues in the (southern) ocean, and the number of Medusæ and Zoophytes are comparatively small. Below the fourth region in depth the number of animals diminishes as we descend, until, in the lowest part of the eighth region, the number of Testacea was found to be only eight, indicating a zero in the distribution of animal life at probably about 300 fathoms.

"In the upper regions the more southern forms prevailed, whilst those of the lower zones presented a northern character (corresponding to the temperature of that region), indicating a probable law, that in the distribution of marine animals regions of depth are equivalent to parallels of latitude.

"Any oscillations of level, however slight, would produce alternations of strata containing distinct groups of organic beings with others void of such; and partial alternations of marine and freshwater beds would be formed, a phænomenon now in progress on the coasts of Asia Minor. All this would occur without convulsions or violent catastrophes of any kind. Changes of level, however slight, might cause the extinction of whole genera of animals and plants, of which only such as hard parts would be preserved. Were the present sea-bottom of the Ægean to be upheaved, whole classes of animals would disappear and leave not a trace behind to assure the future geologist of their having existed."

We find these periodical oscillations of level going on in the Caspian Sea; these, together with the shifting of the position of its waters, partly by the encroachments of deltas on one side and the overflowing of the land on the other, cause some buildings to depress under water, while others are seen risen to a higher elevation; yet these changes are going on as quietly and imperceptibly to ordinary observation as those which must have affected the temple of Serapis.

Lacustrine deposits of the same period may present very different characters, depending on the nature of the locality in which they may be formed: for instance, the lagoons of the Orinoco may contain a very different series of organic remains, as compared with those of the Magdalena; hence formations may be of the same age and the same zone, yot different in de-

grees of induration and organic contents, as well as in their relative geological position. Immense rivers may disembogue themselves into an inland sea, like the Mediterranean, one coming from the south and the other from the north, and thus cause an apparent anomaly in the contents of the deposits. Viewed generally over a considerable area, the rock called chalk is based either upon an arenaceous or argillaceous deposit. As we cannot expect uniformity in the distribution of detritus, unless under conditions which could scarcely ever obtain, we should anticipate that sands would predominate over one part of the area and mud or silt over another, as we now find to be the case in the present deposits forming within the tropics. Some of the white variety may probably have resulted from the precipitation of carbonate of lime from solution in water, in favourable localities, suitable for the reception of calcareous springs.

The supracretaceous group of Europe completes the great sedimentary system of rocks; during the deposition of which it has been supposed man, with the present organic system, came into existence, simply because the remains are principally found in the superficial part of the series, not as fossils, but their bones, a state of things very common to superficial entombments. Some of the larger animals are completely preserved in the ice of the north. These superficial and partially consolidated sediments of sand and mud constitute a large proportion of the dry land of Europe; and there are abundant evidences that they are, comparatively speaking, of recent origin, and that a great portion of the dry lands of the north have been submerged and raised from the sea since they were exposed to a hotter climate. The chalk of the north, the oolite of the tropics, and the coal formation of the south temperate, may be all of the same age; hence it will be observed that the present mode of distinguishing these rocks is only applicable in certain localities, in the same parallels of latitude.

Sir H. De la Beche very justly remarks that "classifications entirely founded on organic remains are at all times liable to be erroneous, if contemporaneous deposition be thence inferred as a necessary consequence, as we have had occasion to observe; they therefore may be considered as doubly liable to error when employed in proving contemporaneous origin in such rocks as those of the supracretaceous period."

Palms and crocodiles are found in these deposits, analogous if not identical to those now found in Africa and in the neighbourhood of the Nile. That a great number of organic beings should have become extinct during such great oscillations of the earth's surface is a natural consequence; it is surprising that so many of the grand stock should have been preserved amongst the numberless vicissitudes of climates, and the separation of continents into islands, and *vice versâ*.

The last group of sedimentary beds pass so insensibly into the superficial alluvial deposits that no line of demarcation can be definitely drawn; we shall therefore close this subject by observing, that the alluvial and loose accumulation of sands, &c. covering the surface of the northern hemisphere, contain principally organic remains belonging, or indigenous, to the south part of the zone in which they are now found. The northern parts of Europe, Asia and America, contain large accumulations of terrestrial animals belonging to more southern climates. This division of the globe is rich in terrestrial relics to the confines of the Arctic seas, all proving the progressive advancement of the lands northward, while the living system gradually retrogrades southward. Hence the cause of the natural conclusion that the northern lands are getting colder, and that the world is consequently populated by Northmen. As the organic contents of the sedimentary rocks are so well described in almost all geological works, we must beg reference to them, trusting that the outline we have given here is sufficient to show the agreement in the order of the sedimentary rocks with the action of the northerly movement of the magnetic force, and that this prime mover, which controls our planet, is equally available to guide us in our researches in sedimentary rocks, as it is in the fundamental series and mineral deposits.

CHAPTER XXVII.

GENERAL RECAPITULATION OF THE ELECTRO-MAGNETIC EFFECTS.

If we now take a general view of the effects of terrestrial magnetism in combination with other secondary agencies really existing, we find sufficient natural causes to explain all the changes which have been observed in the earth's condition, in the degree, combination and sequence which actually belong to them. Each of the phænomena, taken singly, is capable of demonstration in all its details of circumstances by the operations of this great power in connexion with the existing elements.

First.—We have ample proofs of the existence of the magnetic fluid enveloping our globe, and that it affects the condition of the atmosphere; it has two points of convergence, which we call poles; that this fluid has a motion from the south to the north pole, and has an influence on all matter, causing all bodies to be drawn towards the earth, which we call attraction of gravitation, and also tends to cause bodies to arrange themselves in a meridional direction, called polarity, as shown by the magnetic needle; and that the latter action tends to propel all matter northward; and finally, that it acts both mechanically and chemically over the entire surface. We have abundant evidences of the mighty influence of this power over every part of the surface of the earth; the land, ocean, and the air, are all pervaded by it. We find it in the thunder-storm, earthquake and volcano, in the minute molecular actions of chemistry and processes of the living organization. We might expatiate on its apparent influence on a yet mightier scale in the movements and form of the planetary bodies surrounding us in space.

Secondly.—The northerly movement is observed in the ocean, which is found to carry all substances that happen to fall in it from the south to the northern regions. This northerly movement of the elements, and more especially the surrounding ocean, is strongly marked in the configuration of the dry lands. The great continents and many of the islands are more or less pointed towards the south, *i. e.* towards the fountain-head of the oceanic

currents, which are propagated northward in periodical undulations, and are called tides. Thus we observe forces, acting on a vast scale, and through unknown periods of time, yet with a definite polar direction and energy, causing the existing forms of the continents and grooving the channels of the oceans between. The great preponderance of land in the northern hemisphere, and of water in the southern, shows the effects of the northerly movements on the crystalline masses. From the same cause no inland seas can be affected by tides; the bays open to the south are exposed to the maximum, and those open to the north to the minimum effects of the tidal waves.

Thirdly.—The grain of the primary crystalline presents a polar structure in all parts of the world, thus showing the universality of the action and its constant influence in the arrangement of the internal elements. The modification in the transitions of the different rocks, the elongation, fractures and dislocations, show also the general northerly movement of the whole surface.

Fourthly.—Volcanoes and earthquakes appear to be the effects of the chemical action and meridional force of the magnetic currents, according to observations made in South America.

Fifthly.—The formation of mineral veins, their general character, order, and numerous dislocations, prove the action of a polar force; the constant operation of which is essential to account for the observed subterranean phænomena. And if further proof was necessary, we have it in the fact, that it is by means of the laws of terrestrial magnetism alone that we can predict correctly the conditions of any unexplored mineral ground in the primary series.

Sixthly.—This northerly movement co-exists with the formation of our globe, inasmuch as it is the very power that forms a spheroid; it is the increased density of the currents at the poles which is the cause of its oblate figure; and its circulating currents perpetually change the surface of the earth, by bringing the consolidated masses, as they are formed in the southern hemisphere and other parts of the globe, towards the north pole, and thus exposing them to the temperature of different zones progressively; consequently we find the relics of the southern in the northern hemisphere. Such series of beds are never found

in the south, nor is the order of the deposits ever seen inverted. Therefore there is no necessity to invent strange hypotheses to account for the observed facts, but simply to apply the natural operations of nature, *i. e.* the prime mover of terrestrial physics —magnetism, to guide us in our geological researches. The striking and unequivocal order in the organic contents of the sedimentary series is such a coincidence with the natural effects of the polarity of our globe and the various animated covering, as to be alone sufficient to establish the fact of the northerly movement.

Therefore since this power is so extensive, and is the cause of what we call gravitation, its operations are not confined to our globe, but also the whole solar system; and if all space is filled with the magnetic powers of the different celestial bodies according to their respective magnitudes, their movements must be explained very different to the commonly received hypothesis.

CHAPTER XXVIII.

THE PRINCIPLE OF UNIVERSAL MAGNETISM OR POLARITY OF MATTER.

With regard to the absolute diameter of the terrestrial magnetic power which binds our sphere, there are no data by which we can ascertain it; but from the physical connexion of the moon with the surface of the earth, proved by the phænomena of the tides, sap of the vegetation, meteorological influences, and also that observed in the animal world during the lunar changes, together with her orbital motion round the globe, we have reason to suppose that it extends to the orbit of the moon.

To form an adequate notion of the surrounding atmosphere, we must consider it as an aërial shell extending to the orbit of the moon, wrapped round the globe by its magnetic power and revolving with it. The air is dense on the surface and supported by the ocean and dry land; and graduating into extreme tenuity as it extends towards the lunar orbit. Within the great

sphere thus encircling us, invisible but for the gathering of its aqueous part into clouds and vapours, occur those incessant actions and internal changes to which we have adverted.

If, then, the aërial ocean, with its magnetic power, extends to the moon, we may presume from analogy that the satellite floats upon it, and may possibly be carried round the earth by means of a circular current; and that the planets may be sustained and revolve round the sun on the same principle, as they all circulate round that body in the same direction. The sun rotates on an axis nearly perpendicular to the orbit. In round numbers, fourteen rotations of the sun impart one orbital revolution to the earth; twenty-eight rotations of the earth impart one orbital revolution to the moon, and all in the same direction, *i. e.* from west to east. Here, then, we have an analogy with what we see produced by circular motion of fluids, moving in one definite direction by a prime mover; the slower and more majestic movement corresponding with greater dimensions of machinery, and thus impressing on us the prevalence of an harmonious law of action and circular movements, and not mere accidental compound of forces produced by the casual meeting of two forces arbitrarily assumed. Besides, we find constant parallelism of the earth's axis with the axes of the planetary bodies, and we have also experimental proofs of the rotation of magnetic globes by galvanic currents corresponding to the rotation and revolutions of the planets; hence the analogy is complete. We know that bodies may be sustained at any elevation in the air, as well as in the ocean, by adjusting their densities to that of the stratum of fluid in which they may be placed; and that such bodies, like the balloon in the air, or a vessel on the ocean, would continue to revolve uniformly round the earth by a circular current. This is consistent with our daily experience, and according to the well-known laws of nature. No one would presume to say that the clouds are retained in their positions by means of centrifugal forces, and that they would fall towards the earth if such forces were removed. As nature is considered always conformable to herself, we have no right to assume powers different from those that exist; therefore we have no reason to suppose that the moon is retained at her respective distance from the earth by a power different from that which retains the clouds. The moon, as well as the earth, may

be filled with hydrogen, or with still lighter gas for aught we know to the contrary, and which is an opinion infinitely more probable than that of its being filled with igneous matter; consequently a shell containing such a gas enveloped with an atmosphere kept together by the magnetic attraction, would render the moon sufficiently buoyant to float on the external part of the terrestrial aërial sphere.

On the Laws of Motion applied to account for the Circular Movement of the Heavenly Bodies.

Mathematicians think that celestial bodies are sustained in their orbits by means of an original impulse given to them, combined with a centripetal force, and not according to the principles we observe in terrestrial physics; they have laws of motion peculiar to themselves, which have been assumed and blended with the laws of geometry. Indeed, so far as physics are concerned, it matters not much what hypothesis may be adopted in astronomical phænomena, provided our calculations be founded on uniform spaces and velocities; as the whole are reduced to the laws of proportion which subsist between sines and cosines, and not in the least depending on the laws of physics*. Admitting in the abstract that such a space as a perfect void existed, and that a body placed in it would remain for ever at rest; should the body be put in motion by an external force; not a vital principle, nor means of generating a force, but one impulsive action; what would be the consequence according to the established laws of nature founded on experience? According to terrestrial physics, experience and analogy, all impulsive or projectile forces which cannot accompany a body thrown into space, depend on the expansion of a power previously concentrated: the length of the path through which it will be carried can only be equal to the amount of power communicated. A boiler full of steam (or gas) is a power, but cannot produce any action without expansion; but

* Many persons who read and admire the degree of correctness of our almanacs in predicting the eclipses, tides, &c., suppose that such predictions are founded on the law of gravitation; but the fact is that such calculations are entirely dependent on the direct observations of the periodical movements of the heavenly bodies, &c., and have nothing to do with the physical theories of the universe. The ancients made similar calculations at a period when their doctrines were very different.

immediately on allowing it to expand it will produce effects proportionable to its density, the force of which, if not supplied by some generating power, will diminish inversely as the cube of the volume increases in space. The ultimate extent of the expanding power carrying the film or body need not be considered, but its variable force and velocity; these are the questions at issue.

We know, and it has been proved experimentally, that an impulsive force, which is necessarily limited in its amount, has an evanescent quality, and consequently any body or point carried by it commences with a maximum force and velocity; it cannot describe equal spaces in equal times; "like causes produce like effects, or, in similar circumstances, similar consequences ensue;" the force must therefore diminish, and consequently the velocity, inversely as the volume increases, until it finally arrives at a state of rest, *i. e.* a state of equilibrium between the limited impulsive power imparted and the actual effect produced. Indeed engineers are so much accustomed to the above law of forces that it requires but little comment.

When a ball is discharged, it is not the mere resistance of the air and the earth's attraction that reduces the velocity and brings it into a state of rest; it is the *evanescent quality* of that power which had put it in motion: the resisting medium and the attraction of the earth only *diminish the extent* of its path. According to the doctrine of gravitation, neither the radial attraction of the planets, nor a resisting medium, has any influence on the impulsive effect: on the contrary, it is made both *continuous and uniform*, an effect totally inconsistent with the known principles of physics. Had such a doctrine of the laws of motion been founded on correct data, we should have no difficulty in effecting a perpetual motion. What an amount of ingenuity, labour and expense, have been thrown away on the pursuit of the perpetual motion, which might have been turned to better use, if the simplest laws of terrestrial physics had been consulted instead of mere geometry, *i. e.* that no motion can take place and continue without the presence of an active principle! It is time to remove the mist which has so long enveloped physical science, and sweep off some of those intricate calculations which have obstructed the path, and make it easy and clear to all. Natural philosophy may thus become regarded as it ought to be, a fountain of intellectual recreation capable of being enjoyed by all, to the

injury of no one; on the contrary, adding to the practical aid and advantages of our fellow-creatures, cherishing an unbounded spirit of inquiry, free from all prejudices, and open to every impression of a higher order, and affording at all times the purest earthly happiness of which human nature is susceptible.

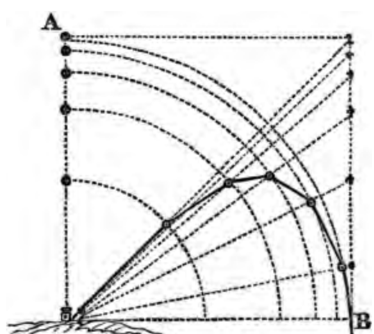
The following extract from a standard work on astronomy, written by one of the first philosophers of the day, will at once show on what foundation the orbital motions of the 'Principia' are based, and how geometrical curves and the paths of projectiles have been confounded.

"All bodies with which we are acquainted, when raised into the air and quietly abandoned, descend to the earth's surface in lines perpendicular to it. They are therefore urged thereto by a force or effort, which we term *gravity*, and whose tendency or direction, as universal experience teaches, is towards the earth's centre; or rather, to speak strictly, with reference to its spheroidal figure, perpendicular to the surface of still water. But if we cast a body obliquely into the air, this tendency, though not extinguished or diminished, is materially modified in its ultimate effect. The upward impetus we give the stone is, it is true, after a time destroyed, and a downward one communicated to it, which ultimately brings it to the surface, where it is opposed in its further progress and brought to rest. But all the while it has been continually deflected or bent aside from its rectilinear progress, and made to describe a curved line concave to the earth's centre, and having a *highest point, vertex or apogee,* just as the moon has in its orbit, where the direction of its motion is perpendicular to the radius. When the stone which we fling obliquely upwards meets and is stopped in its descent by the earth's surface, its motion is not towards the centre, but inclined to the earth's radius *at the same angle as when it quitted our hand.* As we are sure that, if not stopped by the resistance of the earth, it would continue to descend, and that *obliquely*, what presumption, we may ask, is there that it would ever reach the centre, to which its motion, in no part of its visible course, was ever directed?

"What reason have we to believe that it might not rather circulate round it, as the moon does round the earth, returning again to the point it set out from, after completing an elliptic orbit, of which the centre occupies the lower focus? And if so, is it not reasonable to imagine that the same force deflects the

moon at every instant from the tangent of her orbit, and keeps her in the elliptic path, &c.? . . . . It is on such an argument that Newton is understood to have rested his law of gravitation *."

If a body thrown up at a certain angle, say 45°, will descend again at an angle of 45°, it follows that if thrown sufficiently high it would escape the earth altogether, and possibly revolve round it: but what is the *fact*? It is, that bodies *do not* return at the *same angle*. Suppose a stone was thrown up at an angle of 45° with a force which would carry it to an elevation of 500 yards, it would on its near approach to the earth descend almost *perpendicular*. It commences with its maximum angular force, which exceeds that of the radial attraction of the earth proportionably to the sides of the parallelogram of which its path is a compound; at its greatest elevation the radial attraction and the impulsive force are in a state of equilibrium; as the latter rapidly decays, the former being constant and accumulating, the stone returns, and the angular or tangential force becomes evanescent, until at length the stone is left to the sole action of the radial attraction of the earth, and therefore must proceed towards the centre. Those who may not feel disposed to prove the above mathematically, or who may prefer having an ocular demonstration of the fact, may have an illustration in the path of a stream

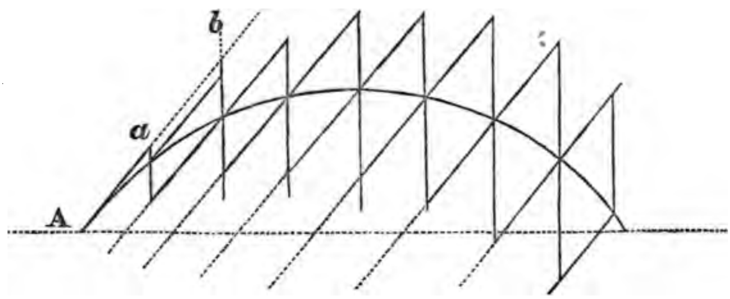


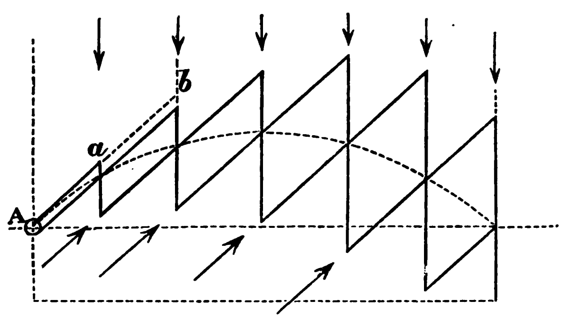
of water forced by a strong pump at a given angle, when it will be observed that the curve of the stream of water, instead of forming the same angle at each extremity, will be very different. The impulsive force will be exhausted at A and B.

* Herschel's Astronomy.

To suppose that the moon is retained in a circular path round the earth by a *projectile force*, is contrary to analogy, and cannot be demonstrated.

The parallelograms commonly described of the composition of the projectile and gravitating forces, are very erroneous; and it is somewhat surprising that they have not been long ere this corrected. A projectile force can neither be constant in direction nor uniform in velocity throughout the curve described.





According to the *theory of projectiles* taught in schools, it is supposed that "if a cannon-ball be shot from A in the direction A *b* (described above), and its original velocity be such as would carry it through the space A *a* during one second, then, if not subject to gravity, it would proceed in a straight line and arrive at *a* in one second, at *b* in two seconds, and so on. Gravity would cause it during the first second to fall sixteen feet, and by completing the parallellograms the following arc is described," and by means of such assumptions it is supposed "that the ball moves in a curve and falls in the same angle as projected."

In the above parallelograms we can readily admit the paral-

lelism in the vertical action of gravity, within the range of a cannon-ball, but we cannot conceive how a force emanating from the cannon's mouth, fixed to one point, and only capable of imparting that force at that point, could act in the oblique parallel lines shown in the figure. In the vertical direction we find the space described by the ball gradually diminished, until at length the upward force is exhausted, and the ball brought back solely by gravity. Why should the projectile force be constant and uniform at an angle of 45°?

After entering into various formulæ and theoretical deductions, we find the following observations:—

"In all these calculations the air has been neglected; the introduction of which complicates the problem so much as to render it one of the most difficult in dynamics, and one which *cannot be said to be even yet reduced to a practical form.* The calculations of gunnery are therefore *necessarily founded on experiment* rather than theory. According to theory, the path would be a perfect arc at each extremity; whereas, in the actual path of a projectile, the descending branch is always shorter and steeper than the ascending one, *and falls more perpendicular.*"

This requires no comment; it is like the theory of the tides, and many others, valueless in practice: it will be observed by the preceding diagram that the ball must necessarily drop nearly vertical on reaching the ground. Besides, were we to grant even the construction of such parallelograms, it would be impossible to make a complete circle, so as to bring the ball back to the point whence it was projected.

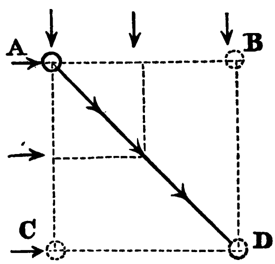
If, then, we find that a body put in motion by one impulsive action must ultimately come into a state of rest without any resisting medium, how much sooner must it exhaust its force if opposed by other forces, and especially if the latter should be constant! A straight line divided into equal parts is one thing, but to produce a force to describe such parts in equal times is another; the former is controlled by the laws of geometry, the latter by the laws of physics. This is the secret link which has been used to preserve the curvilinear doctrine of gravitation; without which tie it could not stand, and must be well known to those who have studied the 'Principia.'

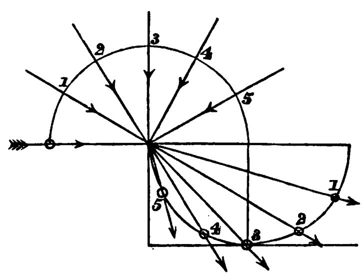
It was once proposed as a prize question by the Academy of

Science at Berlin, to determine whether the laws of motion were necessary or accidental; that is, whether they were to be considered as mathematical or as physical truths. An attempt was made to deduce them from a metaphysical principle of the minimum of action in a very complicated and fanciful nature, the intricacy of which only tended to envelope the subject in still greater obscurity; while the fundamental laws of motion are easily demonstrable from the simplest physical truths. Motion is a change of place, which matter cannot possibly effect of itself; motion is not a property of matter; it can only take place during the excitement of some active principle, and the space described is the measure of the amount of power consumed.

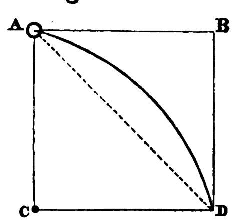
We find that the diagonal of the parallelogram of two forces represents the magnitude and direction of the compound; but we must always bear in mind the distinction which exists between *statics* and *dynamics*. In the former it matters not how the sides of the parallelogram are accumulated, whether slow or quick, by small quantities or by large quantities; as long as the amount of the forces is represented by the length of the sides, a straight diagonal will represent the compound when in a state of equilibrium. The laws of dynamics are not confined to the extreme limits or the mere gross amount of the forces, but they embrace also the nature of their accumulation; we have to analyse the component parts and consider them in connexion with space and time. Speaking *geometrically*, the sides of the parallelogram may be of equal length, and therefore contain an equal number of parts; but that is no reason that such parts should be described in the same time. *Time* is another element, and independent, having no necessary connexion with pure geometry; it belongs to physics, and if we combine the movements of one with the laws of the other we must do it legitimately. The laws of proportions of one are definite and unalterable, whilst the movements produced by the other may be modified according to circumstances. If we describe a circle, we find it in its usual exact proportion; if we apply motion and time to describe a circle, we must adopt them for it, *i. e.* according to their own peculiar properties, and not *solely* by geometry. We are told that the planets are retained in their orbits simply by means of two forces, the tangential and centripetal; and that if one of the

two forces were taken away, these bodies would be either carried off in a tangential direction, or fall to the focus of the centripetal action. If a body put in motion by a uniform force in one definite direction be met by another body moving at right angles to it by a similar uniform force, they will form a compound at the point of contact, which will be equal to the diagonal of the parallelogram of the two forces, in direction and magnitude; and as their respective forces were uniform, the compound will be uniform and straight, as described in the annexed diagrams:—

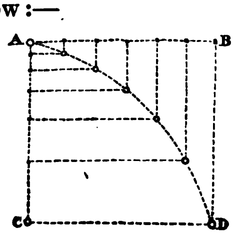




If the perpendicular be an increasing force and the horizontal a uniform one, the following curve will be described:—



This arc will be formed by an increasing velocity until the body arrives at D, where it will require another tangential force at a right angle to the direction of the former to complete a semicircle, and also corresponding parallel lines of gravity instead of the radial to describe the parallelograms, as the following figure will show:—



Suppose the body set in motion by an impulsive or a variable force be met by a uniform force, the diagonal will be described by a variable velocity, and in a curvilinear direction. If the two forces be variable in the same ratio, the diagonal of the parallelogram will be straight, but described by a variable motion. If we require the compound to form a *circle*, and to be described in *equal times and spaces*, the radius and velocities remaining constant quantities, the centrifugal and centripetal must be constantly equal; but in order to form the circle the tangential must possess the power of *perpetually changing its direction*, in a word, a *circular motion*; without this the orbit cannot be described by the compound. The continuation of the parallelogram beyond the quadrant would at once show the necessity of a fresh impulsive force applied at right angles to the former; and the circle is even then of variable velocities in each quadrant. It is therefore made evident that such conditions are not only contrary to the laws of terrestrial physics, but also contrary to the compound of the assumed forces.

It must not be forgotten that an arc, although bounded by the same extreme limits in a parallelogram, however small it may be reduced, cannot be considered as a straight line. Any attempt of making rectilinear and curvilinear figures equivalent by reduction, must be considered as merely merging into indivisibles and inadmissibles, if there be any truth in the laws of geometry. Indeed the question on the condition of forces necessary to produce given effects is clear and divested of all metaphysical obscurities, not requiring the differential calculus, and other methods of geometrical analysis that are so objectionable in their logic and conclusions. All we require to account for the moon being retained in her orbit, and the planets again in the atmosphere of the sun, and all moving in one definite direction, is the admission of magnetism, *i. e.* that mysterious power which we *know* to exist, circulating from pole to pole of every individual body, with a power varying inversely as the square, or rather as the cube of the spheres, rendering the respective compounds or fluids of each body of variable density; and this again accompanied by an equatorial current or circular motion; being an essential property of magnetic forces.

The application of the Newtonian laws of motion to the

comets is still less satisfactory than it is to the planetary bodies. The comets appear to be gaseous bodies as rare as vapour; yet it is assumed that bodies so light move towards the sun, and pass through its dense atmosphere by means of tangential and centripetal forces. Conceive a body, say a feather, to be drawn from a distance by means of a radial power increasing in force inversely as the square of the distance diminishes, and that it should arrive at the focus of such an intense radial power, and then turn round and move again from it, simply by means of the velocity generated in moving towards it, and thus continue to circulate in an elongated ellipsis round such a centre: it is contrary to all analogy: and it is truly extraordinary that such notions should have been encouraged for one moment. If we apply magnetism, and assume that the sun is governed by a similar power, we have no difficulty in explaining the nature of the motion of comets. According to the laws of magnetism, a combination of magnetic globes in a state of equilibrium will have their respective poles dissimilar, *i. e.* the north end of one corresponding to the south end of the other. Hence it follows that the pole of the moon corresponding to our south pole must be the attractive, and that the pole of the sun corresponding to our north pole must be the repulsive. If a comet were a luminous vapour, like the aurora borealis, moving by the polar currents of the sun, it would necessarily move nearly at right angles to the orbit; and such are their paths. If, again, we consider them as mere solar magnetic sparks, they must be conveyed by the polar current to the attractive pole, and issue out again at the negative pole, and thus continue their circular motion from and to the axis of the sun by the magnetic currents of the solar system. The light of the sun is too intense to examine minutely the effects of these bodies near it; however, we find that in passing through the axis they present the appearance of a solar aurora borealis and australis.

Their variations in apparent size during the time they continue visible, are no less remarkable than those of their velocity: sometimes they make their first appearance as faint and slow moving objects, with little or no tail; but by degrees accelerate, enlarge, and throw out from them this appendage, which increases in length and brightness till they approach the sun and

are merged in its beams; after a time they again emerge on the other side, receding from the sun with a velocity at first rapid, but gradually decaying. It is after thus passing the sun, and not till then, that they shine forth in all their splendour, and that their tails acquire their greatest length and development, thus indicating plainly the action of the sun as the exciting cause of that extraordinary emanation.

A similar circumstance has been remarked also in the change of dimensions of the comet of Encke in its progress to and from the sun, viz. that the real diameter of the visible nebulosity undergoes a rapid *contraction* as it *approaches*, and an equally rapid *dilatation* as it *recedes* from the sun, owing probably to its passage through the axis. Cometary bodies may appear, in looking at them in the heavens, irregular and capricious in their paths; but a careful observation will show that they uniformly move to the same pole and emerge from the opposite; and more or less at right angles to the orbits. They may also pass through the axis of the planets in a similar manner, thus producing the phænomena of the aurora borealis and australis.

To conclude, we may reasonably consider that by this power the stability of the solar system is maintained, and the form of the celestial bodies shows that it is an active agent in each. Nor is this universal power confined to our own system, but extends as far as telescopic vision can determine in the immensity of the works of the creation. This wonderful power is present in all things visible and invisible, like a mysterious and universal spirit controlling the vast works of the universe. Yet although so great and so various in its effects, its laws of action are so simple as to be within the reach of our comprehension. It is like a wheel within a wheel working myriads of other wheels within its sphere of action; we find it in the minutest microscopic crystal, in the aggregation of crystals which constitute a continent, in a word, in our globe bodily; this again governed by the magnetism of the sun, and probably the sun by a still larger body, until we are lost in its immensity. It is vain to proceed further; the more we progress into the regions of space the deeper we merge into the impenetrable mysteries of the creation, and the greater becomes the diameter of the surrounding darkness, which expands far beyond the sphere of human imagination. Although

the harmony and uniformity of the system may be thus preserved for ever, exhibiting no change, no beginning nor ending, yet we find in our terrestrial habitation, *i. e.* the earth, the seat of man, that it is but the production of a season, and subject to decay like animated nature: the spot on which we exist will by the same harmonious law, independent of the globe itself, ultimately disappear, and be reduced to its primary elements at the north pole. Great Britain, and other countries which are situated in the same parallel, will in a very few thousand years vanish from the surface of the globe, and other more southerly lands will take their place. As already stated, the electro-magnetic power which controls our planet by the circulation of its movements, renders the southern hemisphere the spring of our terrestrial habitation, the equator its summer, the northern hemisphere its autumn, and the north polar basin its final dissolution. Hence geology and magnetism is a science that cannot be surpassed in the maguitude of its utility nor in the sublimity of its objects: not only is it next to astronomy, but it forms one and the same system of physical operations; and instructs us that we are placed in a part of a scheme—not a fixed but progressive one—ever-changing—no permanent resting-place, one generation passing into another by succession, and merging into eternity—every way incomprehensible; incomprehensible in a measure equally with respect to what has been, what now is, and what shall be hereafter to the end of time.

CHAPTER XXIX.

ON THE GENERAL APPLICATION OF THE LAWS OF TERRESTRIAL MAGNETISM TO THE USEFUL PURPOSES OF LIFE.

NOTWITHSTANDING the existence of magnetism has been so long known, and turned to account in navigation and general surveying, and has been the subject of numerous experiments and theories, the application of this principle, beyond that of the above, has been of a nature purely local, confined to mere toys,

until very recently, and never has been duly considered in the magnitude of its effects and universal character in the manner now brought forward. A detail of all the various useful application of which this universal principle is susceptible, would occupy volumes, as it embraces all phænomena now classed under the head of gravitation; it has an intimate connexion with our proceedings, we are at all times enveloped by it and permeated with it, and we are always under the immediate dominion of its laws, which laws are found permanent, consistent, intelligible, and discoverable with only a moderate degree of research. Hence, since it is certain that such a principle exists, it is manifestly of the utmost importance to study its laws and to know how to apply them, were it for no other reason than to enable us in all we undertake to have at least the laws on our side, so as to avoid struggling in vain against difficulties opposed to us by natural causes.

It is the variation in the density of the enveloping magnetic fluid which is the cause of pendulums of equal length varying in the number of their oscillations in a given time in different latitudes; and in order to make them keep correct time, it is necessary to vary the lengths respectively according to the variation in the intensity of the radial attraction in each latitude. We find also that the zones of equal density in the atmosphere are not at equal heights in different latitudes, and therefore in making barometrical measurements the formulæ should be made to correspond to the variation in each latitude*.

The *polarity* of terrestrial magnetism is the mariner's faithful guide when enveloped in darkness on the boundless ocean; and he knows that if masses of iron be placed near the magnetic needle it becomes disturbed and rendered useless. The knowledge of the cause of such disturbances for its safe application is as essential as that of the principle itself; and still more so, as it will protect its possessor from being misled by inventions which pretend to neutralize the effects of local attraction. The law of magnetic action will show what is within the limits of possibility and what is not; and that the less the natural cur-

* Whilst making my barometrical observations near the equator, I found that the old formulæ were of no avail, and I was obliged to make a new table for determining the correct elevation by the barometer.

rent is disturbed, the more correct must be the indication of the needle.

We are to consider magnetism as a stream of subtle fluid constantly moving from south to north; should it be disturbed from its natural course, nothing short of the removal of such disturbances can give its true direction. The author made several experiments on this subject on the Pacific and during his voyages from South America to England; therefore he speaks from experience, as well as from deductions founded on experiments. The most important points to be attended to are the following: to make the needles in the best form for retaining their magnetism, and in such a manner as to allow the currents to enter and issue out at two points diametrically opposite, *edgeways* and not flat, and that the current may pass through without being interrupted by a dissimilar metal; and to place such needles in situations sufficiently distant from local disturbances*.

Variations.

The charts of magnetic curves of variation are drawn at present in a manner that tends to mislead persons. Instead of laying down the direction of the needles as they would naturally appear when left to the sole control of the magnetic stream in their undulating meridional lines, they are marked in the most confused manner with irregular inflections of curves, indicating a total want of symmetry, and thus complicating the question of variation by lines which have no necessary connexion, productive of no advantage, but of much real injury to the problem itself. On reference to a chart, it will be observed that it contains two distinct lines, which are called lines of no variation; the western passing in a north-west direction from the South Atlantic Ocean to a point *called* the magnetic pole, round which a series of lines are drawn, having the appearance of a general convergence towards it, which on a superficial inspection leads to the idea that they represent the actual direction of the horizontal needle, which is by no means the case: what is called the eastern line of no variation is much more irregular, being full of loops and inflexions: it begins in latitude 60° south, below New

* A vertical stream has a more powerful and correct polarity than a flat one, analogous to the vane which indicates the direction of the wind.

Holland, crosses that island through its centre, and extends through the Indian Archipelago with double sinuosity, so as to cross the equator three times: it then stretches along the coast of China, making a semicircular sweep to the west till it reaches the latitude of 71°, where it descends again to the south, and returns northwards with a great semicircular bend, which terminates in the White Sea. In the Pacific Ocean we find elongated ovals described; what the centre of such ovals intends to represent it is difficult to imagine. Such is the confused manner in which the direction and variation of the magnetic needle are represented. If the chart were compared with Plates IV. and V., on which the same magnetic meridians are indicated by the arrows, it would scarcely be believed that they represented the phænomena intended to be described by these charts. It is to be hoped, for the sake of mariners as well as for the progress of science, that the lines will be shown in their simple natural state, and that the phænomena will not be confused with unmeaning lines, to suit formulæ which can never be of any utility.

Magnetic, or Electro-Magnetic Currents.

It may be supposed from the apparent facility with which some persons attempt to account for the numerous natural phænomena, and so readily state that they are the effects of electricity, and by their *positive* and *negative* terms employed and transposed according to fancy, that there is some *positive* meaning in their notions of electricity.

Notwithstanding all their writings, few of them are able to give a satisfactory answer to the simple question, 'What is electricity?' nor yet a definite meaning to the terms positive and negative. It will be observed that this work is confined more or less to what we know and what we can prove by experiment; and also such as we are able to apply usefully in practice, thus demonstrating the truth of the general principles. It has been shown in Chapters I. and II., that the currents move from south to north in the magnet; that they move from the zinc plate to the copper or silver plate in the battery; and that the two ends or two poles absorb at one end and evolve at the other, and thus continue while the exciting cause is present.

By knowing this, we can apply the current not only to decom-

pose and recompose according to the direction in which it acts, but also to etch steel plates. It has been shown that when the connecting wires of a battery are brought together a spark ensues, and portions of that piece of metal communicating with the zinc are transferred to the metal communicating with the silver. From a steel plate attached to the copper wire of the zinc in a moderate-sized battery, with a platinum or gold pointed end to the wire connected with the silver plate, the following results may be obtained. In moving the latter along the face of the steel plate, a portion of the steel face is thrown off and transferred to the etching wire, by means of the intensity of the stream coming out of the steel and drawn into the pointed wire, whence it is conveyed towards the silver plate to be evolved: thus by electro-mechanical skill and a knowledge of the laws of action, a perfect device can be made upon the hardest steel. If the plate and tracing wire be connected to the reversed plates of the battery, the effect is different; the current rushes out of the platinum or gold point from the zinc, and the latter flies off and is precipitated on the steel plate, thus forming any design in relief that may be traced. Numerous other effects may be noticed; but the above, with the previous illustrations, are quite sufficient to show the importance of comprehending the laws of action.

When the electric telegraph was first employed, it was thought necessary to fix two wires, viz. one for conveying the current from pole to pole, and another to bring it back again. It was supposed that the very same current which issued out from one pole must be brought back again to complete the circuit. We find that the conductor through which the electrical current is to circulate must be absolutely complete in all its parts to produce the action from pole to pole; no action can be produced without a metallic connexion; the slightest want of continuity of the conducting material between the plates of the battery being fatal to the passage of the fluid. When this is done, all that is wanted to complete the circuit is to convey the wires from each pole to water connected with the sea, thus returning back to this element that active power which is taken from it at another point, being as it were a reservoir in which the power exists, and not a mere conductor of a current back again, as some

imagine. If we substitute the electro-magnetic machine for the galvanic, the effect is the same.

Again, with regard to magnets, we find that a portion of the currents passing through a very short and stout bar returns from the evolving back to the absorbing pole; but when lengthened to an indefinite extent, no such returning action takes place; the external enveloping power is absorbed at one pole, and issues out at the other to restore the equilibrium of the surrounding space*. Thus, by paying due attention to the great laws of action, and not wasting our time in speculating on the *origin* of things, we keep the mind within the limits of experimental demonstrations and usefulness, and render the progress of science more acceptable and more readily appreciated by the community at large. It is pleasing to find that the hints given in the first edition of this work have led to improvements and simplicity in some of the electric telegraphs, which were duly and kindly acknowledged, and I trust further improvements and extension of this universal power will yet be effected in this most important and rapid means of intercourse between nations.

Rocks.

After reading the foregoing pages, it will be observed how essential is the knowledge of *practical* geology, and the general principles herein propounded, to form a just opinion of the structure of the primary rocks, their transitions and modifications. By knowing the general character of the formation, the growth as it were of a series of crystalline rocks, their grain, and the actual laws of the subterranean operations by which they are formed, free from hypothetical notions, we are enabled to make a systematic examination, founded on definite principles, capable of being practically tested.

It is by the composition and structure and geological position that we can determine the metalliferous contents or the value of any series of rocks for building-stones. Rocks are like timber,

* If great intensity of action be required, the two poles must be brought together like a horseshoe magnet; by bringing the absorbing and evolving ends near each other, their respective powers become increased proportionably to the compression of the etherial volume entering or issuing out of the poles respectively.

they are not equally durable in all situations, nor equally compact *in situ*: they vary in compactness and composition, frequently within a very narrow compass.

In slate quarries, the knowledge of the geological position, the obliterated sedimentary seams, the intrusive veins, and order of the cleavage-planes is of paramount importance, not only to arrive at a correct estimate of the value of such properties, but for economical and judicious working. It is somewhat extraordinary that the subject of cleavage-planes, both in the primary and the secondary formations, are so little understood, in a country presenting such excellent opportunities as England, and more especially Wales, Scotland and Ireland. In the first edition of this work, after quoting Professor Sedgwick's excellent observations on the subject of cleavage-planes, I stated that the object was "merely to show the striking coincidence of independent investigations with which I was totally unacquainted during my researches in America." I was delighted at the originality and just conceptions of Professor Sedgwick; yet, I find that the subject of cleavage-planes is at present but little understood by geologists, and is now almost neglected.

However, as the object of these remarks is to draw the attention of engineers and quarrymen to the subject, I trust that the Chapters VI. and XIII., together with the woodcuts and plates, will be sufficient to give a general idea of the structure and geological position, and the essential points to be attended to in the selection of rocks and works of exploration. It is to be hoped also that the planes of cleavage and sedimentary divisions, and other structural joints in such rocks, will be more carefully studied and distinguished by those who feel an interest in this useful science.

Mining.

A general detail of all the phænomena observed in mining would be much too voluminous to render such a work convenient, and within the reach of those who require instructions in their daily avocations. Besides, were the whole concentrated into a small compass, it would be of little avail to some persons. A medical work is useful to a practitioner, but not so to the uninitiated. This little work must be considered in the same light, *i. e.* to supply useful hints to the intelligent miner, aiding

him in his progress in the scene of operations, and assisting him in arranging and connecting the facts which he may have acquired from experience, so as to apply them usefully in the science of mining.

To the mining engineers and mining captains one effect of this great law of terrestrial physics has been from time immemorial of important service to them in carrying on their subterranean works, viz. polarity: without the aid of the compass the underground explorations would be exposed to great irregularity and uncertainty; but when we find that this is the prime mover of all things,—governing the crystals in their birth, causing the veins or lodes, and mineral aggregation, it becomes, necessarily, of inestimable value in mining. By carefully studying its laws in the book of nature, which are daily opened to us in all parts of the world, and these faithfully communicated to us from all quarters, we learn the general character and productive quality of rocks in metals and minerals, and the parts wherein the extraction of the contents may be remunerative, and *vice versâ*.

Those who have had experience in gold mining, and especially in different kind of rocks in the southern hemisphere, not merely as casual inspectors or surveyors, but engaged in the actual operations for years, must observe the great ignorance that prevails respecting the gold formation. We actually find well-educated persons without experience coming forward, giving their notions as advice to the world on this subject, when they scarcely know the real character of the ordinary formation of minerals, much less gold deposits, and these ideas are unfortunately, most improperly, considered to proceed from the science of geology. It is to be hoped the increased intelligence will soon perceive the great difference which exists between theoretical fancies created in the closet and practical science obtained in the field of operation: if theoretical men prefer cherishing the doctrines of past generations, let them do so; but we, as practical men, cannot afford to waste time, or be without the laws which nature daily teaches us.

Having dwelt somewhat largely on the metalliferous character of rocks, embracing almost all the useful metals, and given numerous Woodcuts and Plates, I need not dwell on the subject further, than to recommend mining agents in general to pay

more attention to this interesting question for their own government, and also to remember at all times the responsibility which is attached to the office of giving a report on a property.

The office of inspection and giving a faithful and correct report on any given mineral district, if properly considered, is a very responsible one, and as we are but students during the whole period of our existence, no opportunity should be lost to improve ourselves by correcting the errors of the judgement which must now and then occur in such a difficult and complicated task. The accumulated knowledge of the past and present experience in mining should be carefully preserved for the benefit of the rising generation, and thus to supply elements for a more efficient training, without weakening our practical and industrial strength, on which the prosperity of our race so much depends. Let us gradually polish the substance and preserve the base, not neglecting it to run after a more enchanting shadow, or imaginary advantages to be derived from more refined scientific education in the absence of habits of industry and practice, and the science founded upon them.

General Engineering.

The value of the knowledge of the laws of geological dynamics in connexion with those of terrestrial physics, is so important to engineers as scarcely to require comment; even the descriptive part of the science confined to limited spaces is of great benefit. No work of any magnitude can be undertaken in which excavations, cuttings, tunneling, building and brick materials are not necessary, and without a moderate amount of acquaintance with the composition and structure of the rocks, &c., the engineer cannot make a just estimate of his projected works. The duties of engineers are of immense importance to the community at large; independent of the capital placed in their hands to carry on their works, the lives and safety of human beings often depend on the skill and security of their works. This is particularly the case in mines, and especially collieries; the numerous accidents which from time to time occur in underground operations, show the great necessity of studying these subjects well, so as to improve the practical qualifications of those hard-working men who are very properly placed in such posts. There

is a great difficulty in effecting so desirable an object by the ordinary training or common system of education. Schools of engineering and mining have hitherto failed in effecting the object in view—at best they have only refined the intellectual powers, at the expense of the original strength and sound practical experience. Hence a man of ordinary capabilities, who can read and write, trained from childhood in the natural school of industry, is in the greater number of instances the one that takes the lead, invents, makes discoveries, and reduces them to useful purposes; when he has accomplished the work, the theoretical student may come after to explain the why and because, but very little more. Even in general physics there is such an impassable gulf between the facts and experience of practical men and the assumptions of the mathematicians, that the former take the lead also in chemistry.

"We should always distinguish facts from theories," says Dr. Faraday; "the experience of past ages is sufficient to show us the wisdom of such a course; and considering the constant tendency of the mind to rest on an assumption, and forget that it is an assumption, in such cases it becomes a prejudice, and inevitably interferes, more or less, with a clear-sighted judgement. We should distinguish in natural philosophy our real knowledge, *i. e.* the knowledge of facts and laws, from that, which, though it has the form of knowledge, may, from its including so much that is mere assumption, be the very reverse . . . . . . Why assume the existence of that of which we are ignorant, which we cannot conceive, and for which there is no philosophical necessity?" These apposite observations of Dr. Faraday are strikingly applicable to the igneous theory of geology. The difference is so great between the knowledge acquired by experience and the doctrines assumed regarding our globe, that it may be supposed they belong to different regions; and as engineers must be governed by demonstrative laws, and be responsible for their works, they pay little regard to mere hypothetical assumptions; hence the cause of their neglecting what is commonly termed the science of geology.

The greatest engineers, both of the past and present age, have acquired the most valuable part of their education in the workshops and the fields of operation: their success and celebrity

have been mainly obtained through practice and strict adherence to the laws of nature. A prudent and successful engineer fully appreciates the value of scientific knowledge to expand the mind and to aid the reasoning powers, but keeps geometrical laws wholly independent of physical facts. We cannot discover the properties of matter without observing and making experiments; after we have proved by observation or experiment the facts, we may then reason on the natural consequence by means of mathematics; geology requires the same careful mode of proceeding.

Many have imagined that engineering and mining may be acquired in continental academies; and we have seen students coming from such places with their heads so filled with doctrines founded on assumptions, and abstract science improperly called truths, that when they came to practice, they found to their own, as well as their employers' cost, that the acquired knowledge which they so much cherished was of little avail, and that they had to descend to the mechanical drudgery of experimental laws and practice to render themselves fit for their business. The mining engineer has been peculiarly unfortunate in this respect as regards scientific aid. With the exception of the study of mineralogy, chemistry, and surveying, the ordinary geological science has been of no avail to him.

The intelligent mining engineers, who have acquired their knowledge in the mines, act on the same principle as the mechanical engineers, and thus become, practically, local geologists: they carefully study the order of structure and quality of the different rocks, the dislocations and character of the mineral accumulations, and find these as important to attend to as the tools they employ in the explorations. The productions of our mines are to us of immense importance; the incessantly improved application of the metals may be compared to a river, which, by extending its streams, irrigates the soil and spreads fertility. And if we reflect that this island is merely the focus of the industry created by British enterprise, and that it radiates over all parts of the world, and that the capital is often entrusted to the sole judgement of the mining engineer, it will be evident that he ought to possess sound scientific practical knowledge to ensure success. The time is now fast approaching when theo-

retical knowledge must give way and be modified to suit the rapid march of science founded on observation; and I trust that engineers and miners will find, in perusing this little volume, principles, which will agree with their practice—useful in mining and other terrestrial operations; and that the science of Geology, founded on facts, will soon rise in their estimation and become by degrees of much more importance than the mere study of organic remains and sedimentary beds; and in the course of time become elevated to that of the sublime in magnitude, utility and moral good.

DESCRIPTION OF THE PLATES.

Plate

I. An Illustration of the general effects of the Magnetic Currents on an Artificial Globe.

II. Ditto, exhibited by means of Magnetic Bars and Ferruginous Ingredients.

III. An Illustration of the Refraction, variable sizes of the Celestial Bodies, and different degrees of Temperature, produced by the surrounding Atmosphere.

IV. The two Hemispheres, exhibiting the general Polar Grain of the Primary Rocks, and the Direction of the Magnetic Needles.

V. Ditto, North and South Poles.

VI. The British Islands, Cleavage Planes, &c.

VII. A Section of the Andes. This Plate accompanied a Paper which was read by the Author at the Geological Society, and published in their Journal; impressions from which have been taken for this work, by the kind permission of the Council of the Society.

VIII. Section of Granites producing Gold, and a Plan of the Transition of Granite into Gneiss and Schist.

IX. Recent transition and obliteration of East and West Veins.

The Plates have been reduced from the large original drawiugs merely to illustrate the principles. The Sections of the Andes, Mines, Quarries, &c., on such a small scale could not be made to represent the minute details shown on the originals. To render the work as cheap as possible, the illustrations have not only been reduced to mere outlines, but they have also lost the colouring effects of the large maps, which render the latter more instructive and natural. However, it is to be hoped that they will serve the purpose in view, and enable the reader to form a correct judgement of their general character.

THE END.

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OF CONGELATION
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